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Smart City
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Pre-Standardization Study Report

Unified, Secure & Resilient

ICT Framework for Smart Infrastructure

Bureau of Indian Standards, INDIA

Pre-standardization Study Report

Technical Requirements Analysis of

Unified, Secure & Resilient

ICT Framework for Smart Infrastructure

November, 2017

Version 1.0

Panel on Smart Infrastructure – LITDC/P2
under
Electronics & Information Technology Division Council
Bureau of Indian Standards, New Delhi, INDIA.

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Disclaimer

This report is the compilation of study, findings and views of the members of the Smart Infrastructure Panel under Electronics & Information Technology Department of BIS. This report has been prepared as a Pre-standardization Study by the Members to be considered as a guiding document only. The views/analysis expressed in this report/document do not necessarily reflect the official view of Bureau of Indian Standards. Efforts have been taken to ensure the accuracy and authenticity of the information presented in the report; however, BIS does not guarantee the accuracy of any data included in this publication, nor does it accept any responsibility for the consequences of its use.

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Forward:

BIS is the National Standards Body of India established under the BIS Act 1986 for the harmonious development of the activities of standardization, marking and quality certification of goods and for matters connected therewith or incidental thereto.

BIS has been providing traceability and tangibility benefits to the national economy in a number of ways - providing safe reliable quality goods; minimizing health hazards to consumers; promoting exports and imports substitute; control over proliferation of varieties etc. through standardization, certification and testing.

Under the Bureau of Indian Standards Act, 1986, Bureau establishes Indian Standards in relation to any article or process and amends, revises or cancels the standards so established as may be necessary, by a process of consultation involving consumers, manufacturers, Government and regulatory bodies, technologists, scientists and testing laboratories through duly constituted committees. For formulation of Indian Standards, BIS functions through the Technical Committee structure comprising of Sectional Committees, Subcommittees and Panels set up for dealing with specific group of subjects under respective Division Councils. The committee structure of BIS seeks to bring together all those with substantial interest in particular project, so that standards are developed keeping in view national interests and after taking into account all significant viewpoints through a process of consultation. Decisions in BIS technical committees are reached through consensus. As a policy, the standards formulation activity of BIS has been harmonized as far as possible with the relevant guidelines as laid down by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC). BIS, being a signatory to the 'Code of Good Practice for the preparation, adoption and application of standards (Article 4 of WTO-TBT Agreement, Annex 3)' has also accordingly aligned its standards formulation procedure. There are 14 Division Councils and over 650 Technical Committees that have so far developed over 19000 Indian Standards.

During the 14th Meeting of Electronics & Information Technology Division Council on 23rd April 2015, the need of Development of Indian Standards in New Technology areas like Smart Cities / IoT/ M2M / Big Data / Sensor Network / Active Assisted living etc. was felt as important for BIS to focus on them for study and defining the Indian perspective on standardization aspects in these domains. . After comprehensive presentations and detailed discussions on the subject, the council decided to constitute Two Panels to address the new areas for standardization. The 'Smart Infrastructure Panel', one of these two panels, was constituted to cover the Areas of – Smart Cities (ICT Aspects), Smart Energy, Smart Manufacturing and Active Assisted Living under the Convenor-ship of Mr. N. Kishor Narang, Founder president, Narnix technolabs.

Scope:

The proposed panel shall be required to formulate standards and provide further guidance to council in the field of Smart cities (ICT technology), Smart Homes, Smart Energy, Big Data, Internet of Things, Active Assisted and Ambient Living etc. specific to Electronics, Information and Communication Technology.

To monitor, evaluate and synchronize with the international SDOs pursuing Standards development in the above activities. Based on the development and advancement, corresponding technical committees in relevant area shall be formed for Adoption/Harmonization or developing India Specific Standards in the respective domains.

LIAISON WITH ISO & IEC COMMITTEES

a) ISO/IEC/JTC 1/SG 1 – Smart cities
b) IEC/SEG 1 - Systems Evaluation Group - Smart Cities
c) IEC/SEG 3 - Systems Evaluation Group - Ambient Assisted Living
d) IEC/SyC AAL - Active Assisted Living
e) IEC/ SyC Smart Energy

To liaise with relevant Sectional Committees in the BIS and other SDOs in India to share the perspective of the Global SDO's with SYSTEM ORIENTED APPROACH.

The Smart infrastructure panel, LITDC/P 2 comprises of a comprehensive mix of experts from government, industry, academia, research, design, management & consulting in the relevant fields. Panel held its first meeting on 29th January 2016, and since then it has held 6 meetings and tracked & reviewed the relevant standardization activities in the Global SDOs, Industry Consortia and other relevant Fora. The panel members also reviewed the needs of Indian Stakeholders in the respective domains and identified the Gap Areas in the Standards to meet the Indian Requirements. To address the extensive work multiple Work Groups, Study Groups and Task Groups have been formed to focus on respective areas and share their learning with other members of the panel.

The panel, decided to prepare the pre-standardization study & analysis reports in the identified areas for wider dissemination of the knowledge and concerns as well as to help proceed with Standard Development Activities in the Gap Areas already identified by the panel. Respective task groups submitted the following reports to the Panel during its Sixth Meeting in July 2017:

1. ICT Reference Architecture for Smart Cities/Infrastructure – Anchor – **Narang N. Kishor**
2. Technical Requirements Analysis Report on "Last Mile Communication for M2M/IoT Applications" – Anchor – **Prasant Misra**
3. Technical Requirements Analysis Report on "Common Service Layer Requirements in ICT Architecture for Smart Infrastructure" – Anchor – **Aurindam Bhattacharya**

Consolidation, Editing and Compilation of the three reports into a Single Comprehensive Report by – **Narang N. Kishor**, Convenor, **Smart Infrastructure Panel** LITDC/P2, **BIS India**.

This report is the Consolidated Report of the three Pre-Standardization reports prepared by the panel for wider dissemination to all the stakeholders of Smart infrastructure Ecosystem.

Executive Summary

BIS has taken the initiative for identifying standardization need with respect to India specific requirement for **Unified, Secure & Resilient ICT Backbone for Smart Cities**. For this purpose, the first phase of this work has been released in the form of pre-standardization report. The report contains the following three sections:

1. Last Mile Communication for M2M/IoT Applications in Smart Cities
2. Common Service Layer Requirements in ICT Architecture for Smart Infrastructure
3. Comprehensive ICT Reference Architecture for Smart Cities/Infrastructure

This pre-standardization study report is aimed at wider dissemination of the knowledge and concerns as well as to help proceed with Standard Development Activities in the respective Areas.

This Unified Secure & Resilient Framework & Architecture, if implemented in Indian Smart Cities, shall enable optimization of the ICT infrastructure and help bring down the Total Cost of Ownership in terms of capital and recurring expenditure in the upcoming smart cities deployments.

The Standardization Imperatives:

The society, the business, the infrastructure, the services and all other aspects of the civilization on the planet Earth are going through a paradigm shift in the wake of technological advancements, especially in the field of ICT.

All the ecosystems, be it Smart Cities, Smart Grid, Smart Buildings or Smart Factories now find themselves making three classes of transformations:

- ⇨ Improvement of infrastructure – to make it resilient & sustainable…
- ⇨ Addition of the digital layer- which is the essence of the *smart paradigm*; and
- ⇨ Business process transformation - necessary to capitalize on the investments in smart technology.

All Smart City programmes and projects pursue many common goals including sustainable development, better efficiency, resilience, safety and wider support for citizen's engagement and participation. However, each individual city tends to follow its own approach in smart cities programmes and projects. It is not surprising that the numerous technology activists are very vocal on various Smart Cities forums even though cities cannot be reduced to just "Big Data" and "IoT".

It seems that around Smart Cities there are many wonderful Information and Communication Technologies, high levels of enthusiasm from Software vendors, strong support from top leadership, obvious benefits for a significant amount of the planet's population and no shortage of funding. But, all of these together are not sufficient yet.

The current implementation practices of smart cities are rather disjointed, namely:

- ⇨ Smart Cities programmes and projects are, primarily, local initiatives;
- ⇨ Smart Cities programmes and projects are considered as technology projects;
- ⇨ Numerous Smart Cities interest groups are, primarily, clubs;
- ⇨ Efforts for the development of a common vision are insufficient, and
- ⇨ Typical financing patterns do not promote a common vision, namely the government is funding (to some extent) some cities, which engage technological companies, and the government is funding some technological companies, which engage cities.

As a result, there is no agreed basis for efficient and effective cooperation and coordination between different Smart Cities programmes and projects. There is a lot of duplication of work, developed solutions are not reusable, and the same mistakes are repeated.

The relationship between Smart Infrastructure and Smart Cities needs to be understood in this context: "In a smart city, energy, water, transportation, public health and safety, and other key services are managed in concert to support smooth operation of critical infrastructure while providing for a clean, economic and safe environment in which to live, work and play".

Hence, the perspective in Infrastructure Design for any city has undergone a paradigm shift with advent of convergence and networking technologies, solutions for information, communication, entertainment, security and surveillance; which are beginning to have a profound impact on the way we look at the Buildings' Design (be it residential or commercial) and Town Planning.

A vast body like a city consists of large number of heterogeneous information resources. These include sensors, exchanges between or information from citizens, the various workflows and processes, events that occur, etc. that can together complement the integrated management of smart cities. The relationships of these diverse information resources are complicated and could be complementary, reinforced or redundant relationships. The data gathered can further be processed and modelled, correlated with historic data and other activities performed on it before it can be made insightful and can be presented to offer MIS, analysis, decision support or forecasts. There is also a recursive cycle to the data in a Smart City. Information that is generated is information that is consumed which in turn adds to the information generated which becomes information used again.

One of the objectives of the Smart Cities Mission is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment through application of 'Smart' Solutions by using ICT tools and solutions for improving the quality of infrastructure and citizen services. This has brought the issue of standardization, interoperability and seamless integration of numerous physical infrastructures, utilities and services to the forefront.

Looking at how the market is at an inflection point between talking about what 'smart city' means and understanding how to implement it, the evidence of the shift is in the increasing maturity of the demand side, implementing an Integrated Infrastructure to enable collaborative citizen's services with open data and innovative apps and develop standards and protocols for future city development.

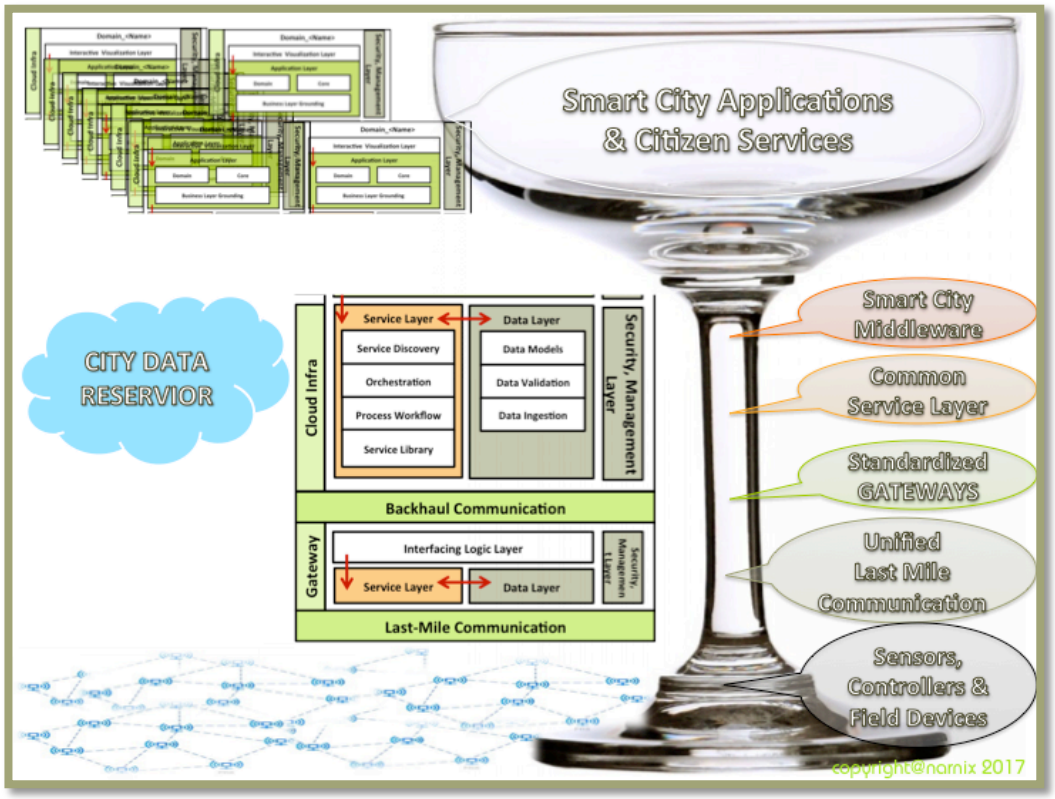
As the Smart city is a complex system of systems, involving many different domains and infrastructures and organisations and activities, it is imperative that all of these need to be integrated and work together effectively for that city to become smart in the real sense.

With this context, the Smart infrastructure panel, LITDC/P2 of BIS has been working towards creating a comprehensive ICT framework to address these problems holistically and comprehensively in order to improve interfaces, avoid unnecessary overlaps and deliver high quality services to all citizens.

This report is an effort by the members of the Smart Infrastructure Panel under Electronics & Information Technology Division Council of Bureau of Indian Standards, the National Standards Body of India to understand the Standardization activities around the globe in context of Smart Cities & Smart Infrastructure; Smart City Stakeholders, Market & Use Cases; and Identify the Gap Areas in Standardization that are critical to India as a Nation.

The essential focus is on "Unified, Secure & Resilient ICT Backbone for Smart Cities/Smart Infrastructure" and members conducted an in-depth study & analysis to **Recommend an India appropriate "Reference Framework for Unified, Secure & Resilient ICT Backbone for Smart Infrastructure"**, which shall enable optimization of the ICT infrastructure and help bring down the Total Cost of Ownership in terms of capital and recurring expenditure in the upcoming smart cities deployments. Implementing and deploying the proposed comprehensive framework in any city for the multitude of heterogeneous & diverse applications use cases and citizen services can achieve this crucial imperative for the smart city stakeholders.

The outcome of the study resulted in evolution of a new Architecture Model -



Classic Saucer Champagne Glass Architecture

The evolved Comprehensively Unified ICT Architecture has been modelled as a **"Classic Saucer Champagne Glass"** with a wide Flat Bottom Base depicting the multitude of Field

Devices & sensors etc. The Saucer Shaped Bowl on the Top, depicting being filled with an ever-increasing spectrum of City Applications and Citizens' Services. The **Long Stem** depicts all the **Common Layers** viz.: the Unified Last Mile Communication, Common Standardized Gateways (application or Vertical Agnostic), the Common Service layer representing the Common Service Functions in the **Gateways**, as well as, in the **Cloud**… and the Smart City Middleware & City Data Reservoir in the cloud.

It is the "Long Stem" of the "Champagne Glass Model" instead of the short & Narrow Neck in the "Hourglass Model" that brings the Harmonization, Standardization & Interoperability in the Architecture, leading to optimization in Operational Efficiency & Life Cycle Cost of the ICT Infrastructure in any Smart City.

It is hoped that if a Reference Solutions based on such an approach could be developed, it could be used as a Road Test for the standards in the field of Unified Information & Communication Architecture for 'Smart City' and 'Smart Infrastructure'.

This Reference Framework shall help define n create **sharable** common elements that shall be interoperable across verticals & hence reduce the Infrastructures' CAPAX & OPEX.

NEXT STEPS:

- ⇨ Develop Comprehensively Granular Reference Architecture for Unified Secure & Resilient ICT Backbone…
- ⇨ Map relevant Standards to the different blocks & Layers of the Reference Architecture & identify Gaps.
- ⇨ Develop New Standards to fill the Gaps.

Background:

Rapid urbanization over the past two decades has led to the mushrooming of megacities (accepted as those with a population in excess of ten million) around the world. The sheer size and scale of these cities place huge pressure on infrastructure development, public services provision, and environmental sustainability. If we add economic, social and ethnic stratification, as well as health, safety and security risks to the list of challenges, the task facing the leader of any megacity seems overwhelming, and is certainly one that cannot be solved by technology alone.

A smart city needs smart governance, smart businesses and smart citizens. A smart city is one that can effectively leverage technology, infrastructure, public policy and citizen engagement to create an urban environment that fosters economic growth and productivity, innovation, social mobility, inclusiveness, and sustainability.

Cities have historically been the centers of economic power of a nation and the megacities of today continue with this trend, becoming economic powerhouses, both at a national and international level, primarily due to the economies of scale that they command. These megacities are able to attract foreign investment, global businesses and top-notch talent from around the world. Ultimately, the virtuous cycle of prosperity and progress leads to microeconomic resilience and improves the ability of the megacity to cope with, recover from, and reconstruct itself after external and internal shocks such as financial downturns, social unrest, natural disasters and epidemics.

Cities, nationally and internationally are main drivers of economic activity: growth and, in the current context, recovery, but this output depends on a comprehensive infrastructure to deliver physical and social resources –the fuel of a City's 'economic engine'. The economic performance of a City is inextricably linked to its physical and communications infrastructures, and the delivery of resources through these infrastructures.

Cities occupy only around 2% of land mass and are occupied by 51% of the world's population and they consume an estimated 80% of its resources. The current global population is 7+ billion, and is forecast to grow to 9+ billion by 2050, by which time it has been predicted that approximately 80% of the global population will be urbanized.

The strain on traditional delivery mechanisms and supply of resources due to increasing populations poses a significant challenge to the sustainable growth of Cities. This applies not only to physical resources, such as energy, water or waste management, but also to social and economic resources, such as healthcare, traffic management and City logistics. As traditional resource delivery systems approach the limits of their capability, there is an urgent need for innovative delivery systems to effectively manage and control resource use in Cities.

Today, we use the term smart city to add technology, Big Data and the Internet of Things to fundamental smart policies, smart governance and smart citizenship. The technology platforms used by megacities need to be designed in such a way so as to enable government efficiency and public access to useful data. This can include cloud computing services, sensor networks and data centers, and traffic management systems for both road

congestion management as well as public transportation systems such as subways and light rail. Policies built on top of these platforms include e-government portals and e-government services that allow citizens access to data on shared Application Programming Interfaces, leveraging the information for community benefits.

Smart City technologies based on digital infrastructure and digital services offer a potential way of monitoring and managing physical and social resource in the city. Digital technologies can collect sufficiently large amounts of data to support very close matching of supply availability against demand requirements. The use of historic information to correlate with actual events can also inform immediate reaction where the data sets match those of a previous historic event. The new communications potential from sensors on buildings, roads and other elements of the City and the sharing of data between service delivery channels, if integrated, will enable the City to improve services, monitor and control resource usage and react to real-time information.

A defining feature of Smart Cities is the ability of the component systems to interoperate. The optimal use of resources across a complex urban environment depends on the interaction between different city services and systems. To identify the most effective use of resources therefore requires communication between the different component systems (e.g. energy consumption monitored by Smart Metering combined with external temperature and sunlight monitoring on the building to reduce the energy consumption).
It is likely that over the next few years, Cities will have to install communications infrastructure that will allow information to be gathered in real time and in regular intervals. There will need to be strategies for optimized data collection and assimilation; and documented good practice in this area would help in the creation of these strategies. In many cases the format of the information - and often the media and protocols on which it is carried - will be different and the communications environment will be highly heterogeneous. As Smart solutions are developed in different sectors, there will be a need for information captured in various infrastructure elements to be shared between service delivery channels. The information will need to be normalized (and perhaps translated), classified and stored.

As the price of technology falls and data analytics become more widespread, what will increasingly differentiate cities is not how 'smart' they are in terms of technology penetration, but the extent to which they leverage technology to bring about innovation, sustainability and inclusiveness.

Better information leads to an enhanced understanding of the behavior of infrastructure. The impact of this will lead to transformations in the approaches to design and construction as well as step changes in improved health and productivity, greater efficiency in design and performance, a low-carbon society and sustainable urban planning and management.

Smart Infrastructure is the result of combining physical infrastructure with digital infrastructure, providing improved information to enable better decision-making, faster and cheaper.

UN Sustainable Development Goal 11:

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning

11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels

11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

Context:

As enumerated in the earlier section, Smart Infrastructure is the result of combining physical infrastructure with digital infrastructure, providing improved information to enable better decision-making, faster and cheaper.

Infrastructure owners across all sectors need to embrace Smart Infrastructure because:
Smart Infrastructure will allow owners and operators to get more out of what they already have – increasing capacity, efficiency, reliability and resilience.
Getting more from existing assets will enable owners and operators to enhance service provision despite constrained finance, growing resource scarcity and, in mature economies, short supply of green field space.
Better understanding of the performance of our infrastructure will allow new infrastructure to be designed and delivered more efficiently, and to provide better whole-life value.

In a world where infrastructure is truly smart, sensing technologies are embedded in infrastructure and the equipment it interacts with. These sensors are connected to a communication backbone, which allows real-time data acquisition and analysis. The information gathered is analyzed, interpreted and delivered as reliable, robust and meaningful information to infrastructure providers, who can then make better-informed decisions about the structural health and maintenance of their assets.

In a sensing environment, infrastructure is able to respond in real time to users' needs. Self-aware infrastructure assets direct their own maintenance, leading to condition-based maintenance, reduced down time and greater operational efficiency of the infrastructure overall.

The so-called smart infrastructure implementations today are vertical centric Silo'd infrastructure which are proprietary solutions, wherein a single vendor owns the vertical application, platform, services, and data (and in certain cases the communication infrastructure as well). This approach inhibits interoperability, data sharing, optimal use of resources and therefore is detrimental to the growth of the industry.

A city is a complex system of systems, involving many different domains and infrastructures and organisations and activities. All of these need to be integrated and work together effectively for that city to become smart, and there are many levels at which integration needs to take place. This is not just integration at a technical level, but also about integration of business processes, management and strategic and regulatory integration.

Hence, a reference Framework for a complex system of systems such as a smart city shall provide a framework that captures the key domains and their interdependences. It does this in such a way as to provide a foundation for the construction of a whole range of useful views and architectures and models that each describe how the smart city works from the point of view of a particular domain, or level of integration or specific use case.

Imperatives:

ICT has been recognized as a true enabler of the smartness in every aspect of the smart city paradigm. But there is a need of consensus among city administration, consulting companies, service companies and technology companies on what ICT components are necessary and how cities should approach this agenda.

Smart Technologies and City scale ICT is part of a new and emerging market where many of the products - both hardware and software, in a multi-vendor environment, and across sectors and services are still being developed. But this, almost nascent smart technologies market suffers from a number of barriers - interoperability, technical and institutional, that need to be overcome if the market is to grow and mature.

In most of the initiatives to make our homes, buildings, cities and/or our planet earth - Green or Sustainable, we are extensively leveraging the ICT (Information & Communication Technologies) solutions to monitor/ control, and hence manage the various aspects of O&M of any infrastructure and services..

While, with intervention of ICT tools, we can achieve major optimisation in the Energy Consumption and Environment Contamination including but not limiting to GHG Emission; we also need to keep in Check the Carbon Footprint of the ICT Infrastructure itself…

In the gold rush of getting our buildings and cities certified as Green or Sustainable, we are adding a plethora of SCADA and Automation systems in every aspect of the utilities & infrastructures. In any Smart Building or Smart City, every service & utility is being automated and being re-enforced with ICT backbone to monitor and control its operation in a most optimized manner. While the attending benefits of ICT backbone for any service/utility are quite commendable, yet there is little focus to optimize the design of the ICT infrastructure itself.

The Smart Cities Mission of the Government of India that backs the use of ICT tools and solutions for improving the quality of infrastructure and citizen services, have brought the issue of standardization, interoperability and seamless integration of numerous physical infrastructures, utilities and services to the forefront.

Several barriers currently exist to widespread deployment of effective and powerful smart city solutions. One key barrier is that many current smart city information and communications technologies (ICT) deployments are based on custom systems that are not interoperable, portable across cities, extensible, or cost-effective. Another is that architectural design efforts currently underway (e.g. ISO/IEC JTC1, IEC, IEEE, ITU and consortia) have not yet converged, creating uncertainty among stakeholders. There is a lack of consensus on both a common language/taxonomy and smart city architectural principles. The result is that groups are likely to generate standards that are divergent, perhaps even contradictory, which does not serve the global smart city community well. A third barrier is the insufficient interoperability and scalability of underlying Internet of Things (IoT), and Cyber-Physical Systems (CPS) technologies that provide the foundation for many smart cities applications. Additional barriers include lack of resources, leadership, prioritization, capability and experience.

Thus, It is imperative to address these problems holistically and comprehensively in order to improve interfaces, avoid unnecessary overlaps and deliver high quality services to all city residents. This report through its in-depth study & analysis highlights the need for adopting a Unified and Secure Framework as well as the relevant standards for Interface Design, Communication Protocols, Data Exchange Formats and System Architecture that support interoperability.

The convergence of multiple networks and technologies, particularly in new and emerging markets involving large-scale infrastructures require a top-down approach to standardization, starting at System Architecture rather than at product level. Such an approach in design not only enables newer and better services, but also allows far greater synergies and cost-effective deployments, thereby reducing the lifecycle (total) cost of ownership of the infrastructure while increasing its attendant environmental benefits and building system resilience.

By laying a common replicable framework, there is an opportunity for the different Smart Cities to leverage State level or National ICT Infrastructure instead of replicating ICT infrastructure, solutions and service across multiple instances. Interest in to cover at least vertical solutions or applications.

Whatever architectures and frameworks we design that provide overseeing guidelines to the stakeholders of respective components and layers of the overall smart infrastructure paradigm; yet it is imperative to work on sufficiently fine granularity of each component and layer for standardization, as well as, harmonization, and ensuring the interoperability among various similar components addressing different applications at semantic as well as syntactic levels. Further the standards being adopted for the smart homes or smart buildings deployments must be harmonized with standards in all other relevant ecosystems and integrated smart infrastructure paradigms. **There is a need to create and suggest frameworks to achieve the Interoperability among all the devices & layers at every interface in the networks**, be it a smart home network, a smart building network, a smart city/community network or the smart grid network that shall enable the stakeholders to prepare a set of detailed standards based specifications to cater to specific/defined/fixed use cases followed by development of a Compliance Testing Framework.

Far-reaching Business Implications of Smart Cities & Smart Infrastructure:

Beyond leveraging ICT in the digitization of Institutional, Economic, Social & Governance Infrastructures of a city, a glimpse into the physical infrastructure brings out a few staggering numbers on the business aspect of this Unified & Secure ICT Infrastructure paradigm and its intervention in a smart city. Consider the scenario in India, as an example:

- ⇨ Smart Cities or NOT, In next five years, more than 250 million Smart Electricity Meters are going to be procured & deployed under the NSGM (National Smart Grid Mission). All these 250 million Smart Meters are going to use Communication Modules and Gateways/DCUs (Data Concentrator Units). At a conservative figure of One DCU/Gateway to 500 Smart Meters, 250 million Communication Modules & 0.5 million DCUs/Gateways shall be needed for the last mile communication in the Smart Metering (AMI) Deployments alone…

- ⇨ Smart Streetlights in next five years, are going to use more than 100 million Communication Modules and at least half a million of DCUs/Gateways…
- ⇨ Smart Buildings are going to deploy more than 50 million smart Sensors and at least 300K – 500K DCUs/gateways…
- ⇨ Similarly, various applications of the Smart Infrastructure paradigm like Smart Water, Smart Gas, Smart Traffic, Smart Environment, Smart Waste Management, Smart Sewage Disposal etc. are going to use a few billions of Smart Sensors with Communication Modules and DCUs/Gateways correspondingly with at the least worst case ratio of 1:100 to 1:500….
- ⇨ Even if, the unified Communication Infrastructure is deployed, the number of sensor Communication modules is not going to reduce; only the DCUs/Gateways needed shall reduce, but shall need enhanced features and design complexities…

To summarize, India ALONE, is going to need a minimum of 8 - 10 billion Communication modules to be integrated into the Smart Sensors and Controllers and 10– 50 million Gateways that shall be needed to operate and maintain the Nation Wide Critical Infrastructure that needs to be deployed to enable and empower the citizens to lead a sustainable, safe and secure life …

All sectors in the infrastructure framework are influenced by the unified ICT backbone paradigm. However, a common infrastructure pool enables the creation of a interconnected and truly homogenous system with seamless communication between Services. Coordination, collaboration and harmonization can be better implemented by the effective use of standards based open, common and shareable, information and communication technologies. The disconnect amongst technological trends being pursued by the stakeholders of the now homogenous smart infrastructure needs to be bridged without any further delay to maintain the Lifecycle Cost / TCO (total cost of ownership) of these individual components within viable economic thresholds.

Scope:

The "Unified, Secure & Resilient ICT Backbone for Smart Cities/Smart Infrastructure" was decided as the major focus area by the Panel, right from the constitution of the Panel on Smart Infrastructure by BIS.

The panel, decided to prepare the pre-standardization study & analysis reports in the identified areas for wider dissemination of the knowledge and concerns as well as to help proceed with Standard Development Activities in the Gap Areas already identified by the panel. Respective task groups submitted the following reports to the Panel during its Sixth Meeting in July 2017:

1 "Last Mile Communication for M2M/IoT Applications"
– Anchor – **Prasant Misra**
2 "Common Service Layer Requirements in ICT Architecture for Smart Infrastructure"
– Anchor – **Aurindam Bhattacharya**
3 "ICT Reference Architecture for Smart Cities/Infrastructure"
– Anchor – **Narang N. Kishor**

The Task Group on *"Unified Last-mile Communication, Networking and Data Transfer Architecture for Smart Infrastructure"* was constituted to conduct in-depth study and analysis to **recommend an India appropriate unified and secure "last-mile" communication, networking, and data transfer framework and architecture**, which shall enable optimization of the smart ICT infrastructure and help bring down the CAPEX and OPEX in the upcoming smart cities deployments. This shall be achieved by proposing a comprehensive unified mechanism for all such protocols and stacks to cross-function **irrespective** of their underlying physical layer technology.

The work flow & plan of the Task Group was decided as:

1. **Review** the **current market and technology requirements** in context of the "last-mile" communication; networking and data transfer in infrastructure applications.
2. **Review** of **ALL** the **candidate** communication technologies, protocols and standards; be it open or proprietary.
3. **Develop and define criteria to benchmark** the reviewed technologies, protocols and standards.
4. **Compare and evaluate** the technologies, protocols and standards against the set benchmarks.
5. Undertake a comprehensive **enumeration of the requirements** to address the current imperatives of the unified and secure "last-mile" framework and architecture.
6. Undertake a detailed **gap analysis** of the prevalent technologies, protocols and standards against the enumerated requirements.
7. Propose the approach and **NEXT STEPS to address the Gaps** identified.

The task group members undertook the study to understand and map various smart infrastructure applications to their technical requirements; so as to identify the potential areas that may need a standardized view for achieving a unified ICT backbone.

The Section presents the technical analysis of the Last-mile communication requirements in ICT architecture for Smart Infrastructure. It is aimed at providing in depth understanding of all the granular technical requirements that any Last-mile communication technology or protocol shall have to be able to address the varied and complex requirements that are common to any and all the infrastructure applications running on the ICT/M2M/IoT platforms in a smart city. The enumeration of these requirements shall set the foundation to identify or develop standards for these requirements to ensure Interoperability through standardized interfaces, to ensure the scalability for new applications addition in future and replication of the same software products in multiple cities.

The Task Group on *"Need for a Common Service Layer Standard"* was constituted to conduct in-depth study and analysis to **Recommend an India appropriate *Common Service Framework and Architecture***, *which shall enable optimization of the smart ICT infrastructure, interoperability of devices and applications, enable data sharing among applications, provide a dashboard to the Governing bodies, provide security as an integral part of the architecture by making Security as a Service; and as an outcome bring down the CAPEX and OPEX in the upcoming smart cities deployments.*

The work flow & plan of the Task Group was decided as:

1. **Review** the merits of a **Common Service Layer** in the Smart City Architecture.
2. **Review** the **current market and technology requirements** in context of the Common Service Layer.
3. Review of ALL the candidate Global standards for the Common Service Layer.
4. Recommend the **India appropriate** Architecture and Standard for adoption in the Smart Cities in India.

The Task Group members undertook the study to review the merits of a Common Service Layer in the Smart City ICT Architecture; and understand & mapped various smart infrastructure applications to their technical requirements so as to identify the potential areas that may need a common & standardized view for achieving a unified ICT backbone.

The Section presents the Technical Analysis of the Common Service Layer Requirements in ICT Architecture for Smart Infrastructure. It is aimed at providing in depth understanding of all the granular technical requirements that any ICT Platform or M2M/IoT Platform shall need to have, to be able to address the varied and complex requirements that are common to any and all the applications running on the ICT/M2M/IoT platforms in a smart city. The enumeration of these requirements shall set the foundation to identify or develop standards for these requirements to ensure Inter-operability thru standardized interfaces, to ensure the scalability for new applications addition in future and replication of the same Software Products in multiple cities.

The Task Group on "Unified, Secure & Resilient ICT Backbone for Smart Cities/Smart Infrastructure" was constituted to conduct an in-depth study & analysis to **Recommend an India appropriate "Reference Framework for Unified, Secure & Resilient ICT Backbone for Smart Infrastructure"**, which shall enable optimization of the ICT infrastructure and help bring down the Total Cost of Ownership in terms of capital and recurring expenditure in the upcoming smart cities deployments. This shall be achieved by proposing a comprehensive

framework for the multitude of heterogeneous & diverse applications, use cases and citizen services.

The work flow & plan of the Task Group was decided as:

1. Review & enumerate the imperatives and merits of Unified ICT Backbone.
2. **Review** the **current market and technology requirements** in context of the ICT Infrastructure in Smart Cities.
3. **Review** the entire candidate ICT Architectures and Frameworks developed either by Global, Regional, and National SDOs or any Industry consortia/ fora.
4. Recommend the **India appropriate** Reference Framework and Architecture for the Common, Unified, Secure & Resilient ICT Infrastructure for adoption in the Smart Cities in India for deployment as a common backbone.

Under this Task, the Task Group members undertook a study to understand and map various smart infrastructure applications to their technical requirements; so as to identify the potential areas that may need a standardized view for achieving a unified ICT backbone.

The Section presents the Technical Analysis of the comprehensive Requirements in ICT Architecture for Smart Infrastructure. It is aimed at providing in-depth understanding of all the granular technical requirements that ICT Infrastructure shall need to have to be able to address the varied and complex requirements that are common to any and all the Infrastructure applications running on the ICT platforms in a smart city. The enumeration of these requirements shall set the foundation to identify the existing relevant standards and develop standards in the Gap areas (identified during the study) for these requirements to ensure Inter-operability thru standardized interfaces, to ensure the scalability for new applications addition in future and replication of the same Software Products in multiple cities.

The Methodology:

The methodology adopted to develop the Comprehensive Technical Requirements is the Systems Approach.

The tenet of system approach essentially mandates the structured and granular steps to address the Standardization requirements in any complex or cross-domain application environment. It considers the Application Environment as a System, in this case considers the "City as a System". Hence, the Technical Requirements enumerated in the document have been derived after in depth study & Analysis, of the Market/Industry Trends & Needs, Stakeholders Identification and their respective needs & objectives; and, all the different use cases for smart city as a system and how they interact with the city/system…

The Technical Requirements derived through this study shall act as the Foundation for the System Architecting. Once the Architecture is developed, the different Standards available in the domain are mapped to the requirements to identify the most suitable standard/standards to meet the requirements. The Standards mapping also provide the insights into the Gap areas where there are NO existing standards, hence need to develop new standards…

Such a systems level approach in design and standardization is likely to not only enable newer and better services, but also allow far greater synergies and cost-effective deployments, reducing the lifecycle (total) cost of ownership of any Infrastructure, be it the smart grid, a home, a building or even a city, with attendant environmental benefits, including carbon reductions and building system resilience.

Approach - A three-step approach has been taken in this study –

1. Review of all the domains with in the Smart Infrastructure Paradigm, applications & use cases; and stakeholders needs & concerns.

2. Study of various ICT Frameworks/Architectures, Common Service Platforms and Last Mile communication Technologies & Protocols for Solutions Deployment with respect to their broad Functional & Technical requirements and different Deployment Models.

3. Architecting the Comprehensive Framework for the Unified, Secure & Resilient ICT infrastructure including the Common Service Layer and the Last Mile Communication for deployment in the Smart Cities as a common ICT Backbone.

The Rationale: "Smart City as a System"

All Smart City programmes and projects pursue many common goals including sustainable development, better efficiency, resilience, safety and wider support for citizen's engagement and participation. However, each individual city tends to follow its own approach in smart cities programmes and projects. It is not surprising that the numerous technology activists are very vocal on various Smart Cities forums even though cities cannot be reduced to just "Big Data" and "IoT".

It seems that around Smart Cities there are many wonderful Information and Communication Technologies, high levels of enthusiasm from Software vendors, strong support from top leadership, obvious benefits for a significant amount of the planet's population and no shortage of funding. But, all of these together are not sufficient yet.

The current implementation practices of smart cities are rather disjointed, namely:

- ⇨ Smart Cities programmes and projects are, primarily, local initiatives;
- ⇨ Smart Cities programmes and projects are considered as technology projects;
- ⇨ Numerous Smart Cities interest groups are, primarily, clubs;
- ⇨ Efforts for the development of a common vision are insufficient, and
- ⇨ Typical financing patterns do not promote a common vision, namely the government is funding (to some extent) some cities, which engage technological companies, and the government is funding some technological companies, which engage cities.

As a result, there is no agreed basis for efficient and effective cooperation and coordination between different Smart Cities programmes and projects. There is a lot of duplication of work, developed solutions are not reusable, and the same mistakes are repeated.

To address such negative phenomena, the IEC came up with a new approach to standardisation – systems-level standardisation that provides the context for the traditional product-level standardisation. The systems-level standardisation aims to achieve synergy between uniformity (availability of standard products) and diversity (ability to combine standard and customized products to address unique needs).

The IEC Systems Approach

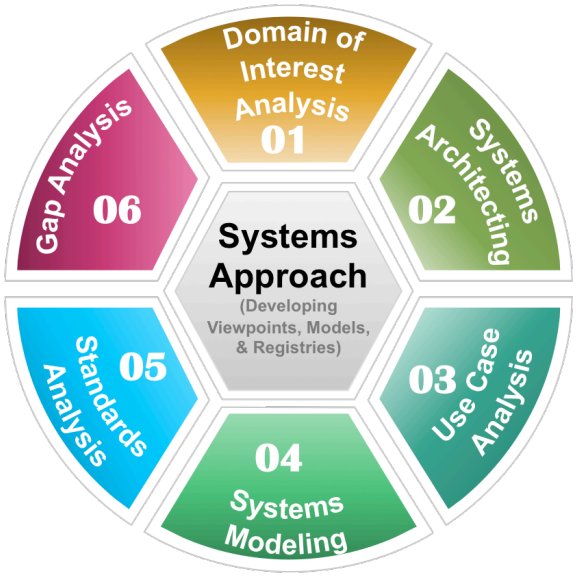
Basics

The systems approach is a holistic approach to understanding a system and its elements in the context of their behavior and their relationships to one another and to their environment. Use of the systems approach makes explicit the structure of a system and the rules governing the behavior of the system.

The systems approach is based on the consideration that functional and structural engineering, system-wide interfaces and emergent system properties become more and more important due to the increasing complexity, convergence and inter-relationship of technologies.

The goal of the systems approach is to walk people and organisations working on complex systems through various stages and steps of analysis and synthesis in order to

- ⇨ Build a comprehensive understanding of the problem space (i.e. abstract domain in which the problem resides) including a list of people and organisations interested in future solutions (i.e. stakeholders);
- ⇨ Outline a set of essential characteristics of the solution space (i.e. abstract domain in which potential solutions to the problem reside);
- ⇨ Architect and engineer a future solution (i.e. the particular system-of-interest) at any desired level of detail.



Six Stages

There are six stages in the IEC Systems Approach. Each stage is focused on an area of understanding about the system. The knowledge gained from each stage builds on top of each other; therefore it is important to follow each stage in order. However, users are encouraged to apply an iterative approach meaning there is no constraint going back to a previous stage with new insights that was gathered in another stage. This "iterative" practice is described as under:

STAGE 1 - Domain Analysis:

- ⇨ This initial stage is crucial in building an understanding of the mission, desired results, or objective that is driven by the market and stakeholders' needs.
- ⇨ Outputs of this stage set the foundation, scope, and boundary of the system of interest.
- ⇨ Outputs from subsequent stages should be traceable to one or more of the needs identified in this stage.

STAGE 2 - System Architecting:

- ⇨ The second stage extrapolates on the first with a purpose to build clarity on the system through general use cases and reference architectures.
- ⇨ The intent of this stage is to build wide breadth knowledge of the system without going into details.

STAGE 3 - Use Case Analysis:

- ⇨ Stage three is focused primarily on developing detailed understanding of use cases identified in Stage 2.
- ⇨ Using the use case methodology in IEC 62559-2, this stage provides guidelines and templates to collect and build thorough Use Cases.

- ⇨ Through these Use Cases, System Requirements can be derived, both functional and non-functional requirements.

STAGE 4 - System Modelling:

- ⇨ In the fourth stage, the Reference Architecture from Stage 2 is modelled in more detail based on the outputs gathered from the previous stages.
- ⇨ Here the system discrete parts, interfaces, communication flow, environment factors, and such are modelled to help build a holistic perspective of the system.

STAGE 5 - Standards Analysis:

- ⇨ In this stage, the focus is on understanding and mapping what relevant standards exist for all the various parts of the system and whether they are contributing or countering the objectives identified in Stage 1.
- ⇨ These standards can include IEC, ISO, ITU and other Global, Regional, National SDO standards.

STAGE 6 - Gap Analysis:

- ⇨ In the final stage, gaps where standards are missing are identified based on the knowledge of existing standards, desired system interaction, use cases and other information gathered from the previous stages.
- ⇨ This will then initiate the activities for the committees to move forward with new standard development.

How to use the Systems Approach:

There are two primary issues to be considered by the users of the Systems Approach:

1. The sequence of stages and steps is not a dogma but a guideline. They can be used in iterative way if necessary.
2. It is recommended to consider some adaptation of the Systems Approach for the users' unique needs - some steps may be omitted or merged.

The systems approach helps to produce the following digital work products:

- ⇨ **Artifacts** (entities made by creative human work) which are used in the problem space and solution space;
- ⇨ **Problem Space Terminology** to explain various concepts from the problem space and relationships between them;
- ⇨ **Solution Space Terminology** to explain various concepts from the solution space and relationships between them;
- ⇨ **Nomenclatures** (or classifications) of various artifacts of the same type;
- ⇨ **Architecture Models** to formally codify some relationships between some artifacts;
- ⇨ **Architecture Views** (collections of models) to address of some concerns of some stakeholders, and
- ⇨ System-of-Interest **architectures** and their **architecture descriptions,** which consists of several views.

To facilitate the production of those digital work products, the IEC Systems Approach provides:

- ⇨ **Systems Approach Terminology** to explain various concepts of the systems approach and relationships between them;
- ⇨ Several artifact definitions;
- ⇨ Several nomenclatures with artifacts related to the systems approach;
- ⇨ Several **Model Definitions** (also known as model kinds);
- ⇨ Several **Architecture Viewpoints** conventions which can include languages, notations, model definitions, design rules, and/or modelling methods, analysis techniques and

other operations on architecture views; architecture views are system-of-interest dependent and architecture viewpoints are system-of-interest independent, and

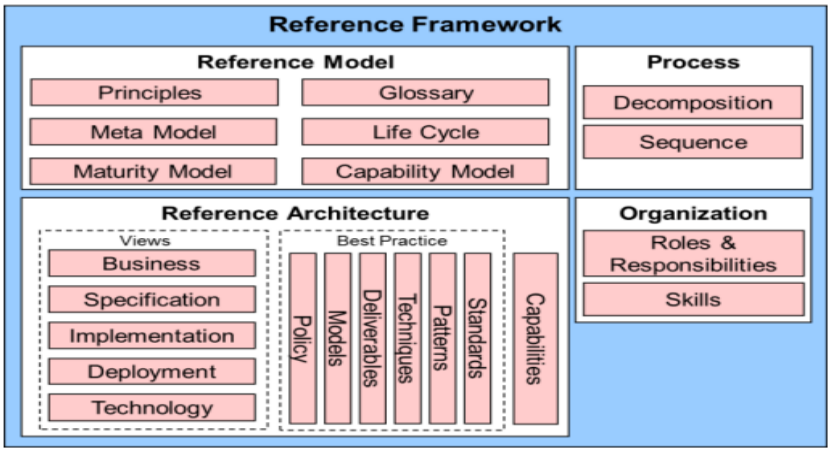
⇨ Several **Patterns** to facilitate creation of some models from other models.

Reference Framework for Smart Cities:

A Reference Framework includes other key models such as Reference Architecture and a Reference Model.

- The Reference Architecture provides a blueprint or template architecture that can be reused by others wishing to adopt a similar solution.
- The Reference Model explains the concepts and relationships that underlie the Reference Architecture.

Developing these different models is a major piece of work, but it provides important tools to help the city better understand what it needs and describe these clearly to the key city stakeholders and to its suppliers.



The systems-level standardisation will offer to Smart City programmes and projects a coherent set of commonly agreed and fully traceable deliverables, namely:

⇨ Reference Model (actually, terminology and, ideally, an ontology) to enable various stakeholders to communicate and collaborate effectively and efficiently.

⇨ Reference Architecture of a Smart City as a system to enable various Smart Cities programmes and projects to compare their implementations, and find both common and unique needs and solutions.

⇨ A coherent set of use cases (how various actors interact with the Smart City as a system) to be sure that the reference architecture addresses various stakeholders' concerns in a good, right and successful way.

⇨ A collection of existing and new standards for implementation of common capabilities of Smart Cities to reuse and share the work.

A particular city can easily adjust those deliverables to its unique needs and speed up its implementation by:

⇨ Accessing knowledge from world-wide experts;

⇨ Adjusting the reference architecture to its unique needs;

⇨ Using proven best practices, and

- ⇨ Re-using some standard building blocks (services, applications, processes, etc.) from other programmes and projects.

The Smart Cities Reference Architecture

Any Smart City is an uber-complex, socio-technical system of cyber-physical systems (e.g. IoT devices and applications) with the following characteristics:

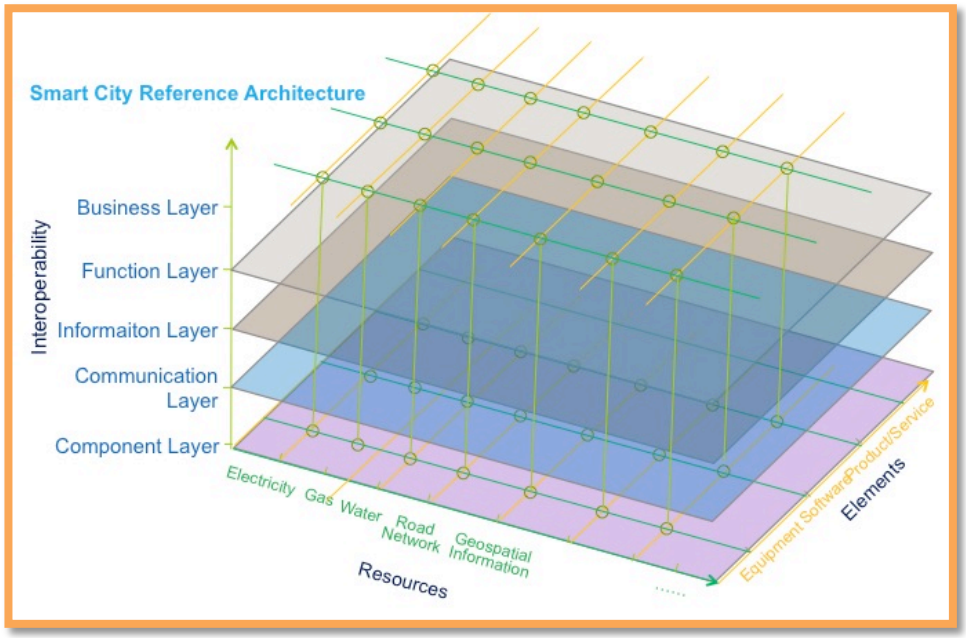
- ⇨ Huge volume of digital data and information
- ⇨ Software-intensive ("software is eating the world")
- ⇨ Distributed and decentralized
- ⇨ Great influence on our society (including economy)
- ⇨ Ability to interact with the physical world
- ⇨ Seemingly mutually contradictory requirements

The Smart Cities reference architecture explains to any stakeholder how future implementations (which are based on the reference architecture) can address his/her concerns and change his/her personal, professional and social life for the better.

The Smart Cities reference architecture explicitly links various stakeholders' needs (or high-level requirements) with the principles of reference architecture to provide end-to-end traceability.

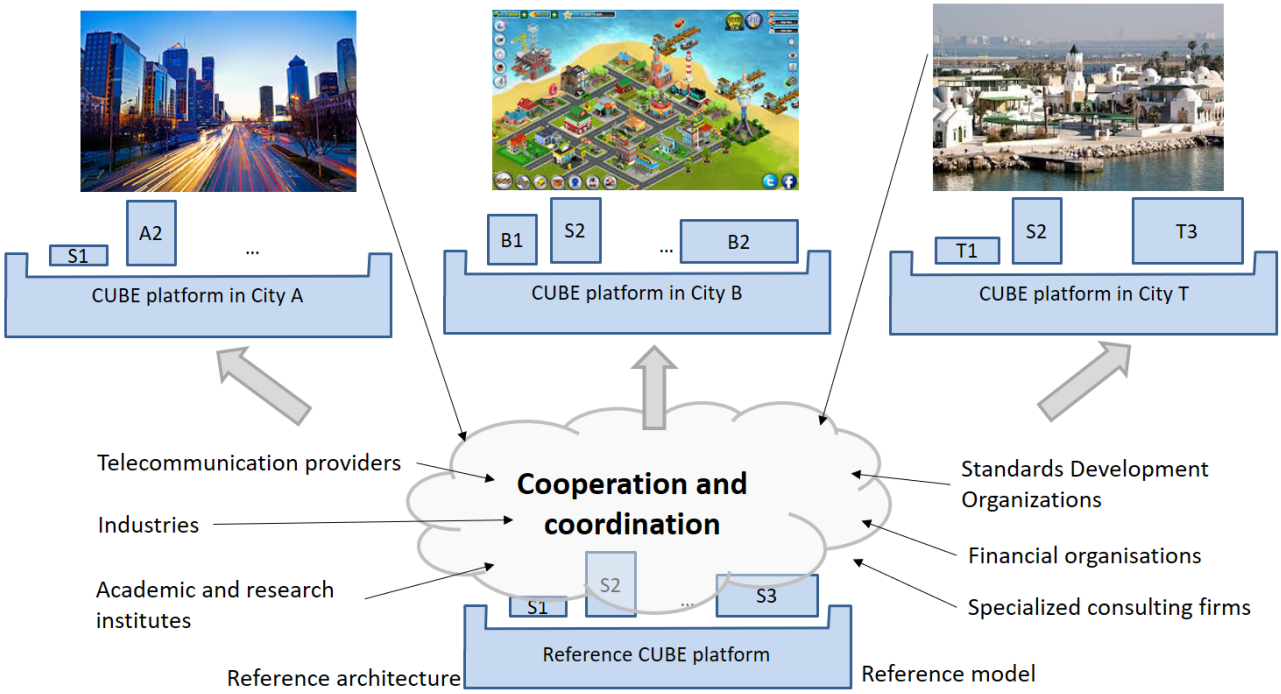
The Smart Cities reference architecture brings a methodological and practical guidance on how to achieve the essential characteristics of your Smart City such as security, privacy, low cost of operations, reduced time to market, etc.

The Smart Cities reference architecture provides a common methodology for architecting systems of systems thus enabling different people in similar situations to find similar solutions or propose innovations that can benefit many cities.



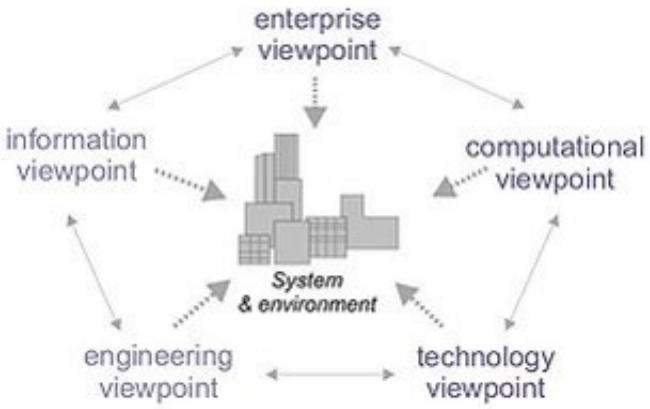
Typical Smart City Reference Architecture

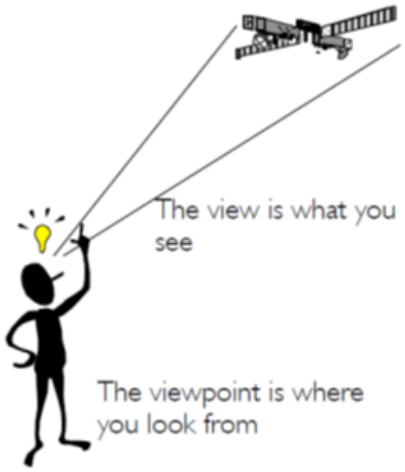
From the systems point of view, the Smart Cities vision can be illustrated by the following figure (CUBE stands for City Unified Business Execution). Using the Smart Cities reference architecture as an implementation framework, various stakeholders coordinate and collaborate on standard building blocks to expedite the implementation of a variety of Smart cities.



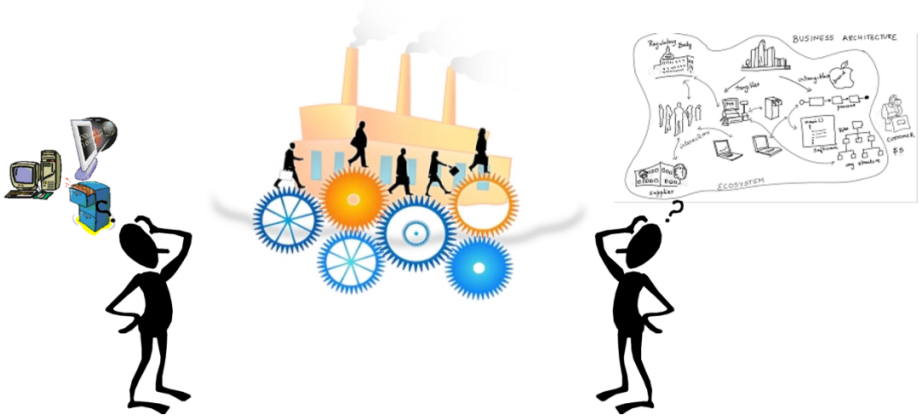
In accordance with ISO/IEC/IEEE 42010, the Smart Cities reference architecture is described via several aligned viewpoints. Each viewpoint is a formalized description of some aspects of the Smart Cities reference architecture. Each viewpoint is a tool for various stakeholders to better understand, manage and implement Smart City programmes and projects. Some of the many viewpoints of the Smart Cities reference architecture are described below.

Many viewpoints and views are possible-





Different stakeholders see the same system-of-interest differently and recognize different artifacts.



Viewpoints

The digital work products defined below are listed in an approximate order because some modifications of a digital work product may necessitate some modifications in some other digital work products.
Please note, that the patterns to facilitate creation of some digital work products from some other digital work products are not mentioned below.

- Value Viewpoint comprises several digital work products, which describe the problem space, and provides some ideas about the future systems and its expected value for the stakeholders.
- Big Picture viewpoint comprises several digital work products, which describe the future solutions as the whole and provide some ideas about their top-level functional structure.
- Capability Viewpoint comprises several digital work products, which describe the future solutions as a set of capabilities (i.e. ability of a system or a system element to do something at a required level of performance). This viewpoint provides sufficient functional and performance information about any future solution to initiate its detailed engineering.
- Engineering Viewpoint comprises several digital work products, which describe the future solutions as sets of artifacts such as processes, service, functions, data, information, etc.

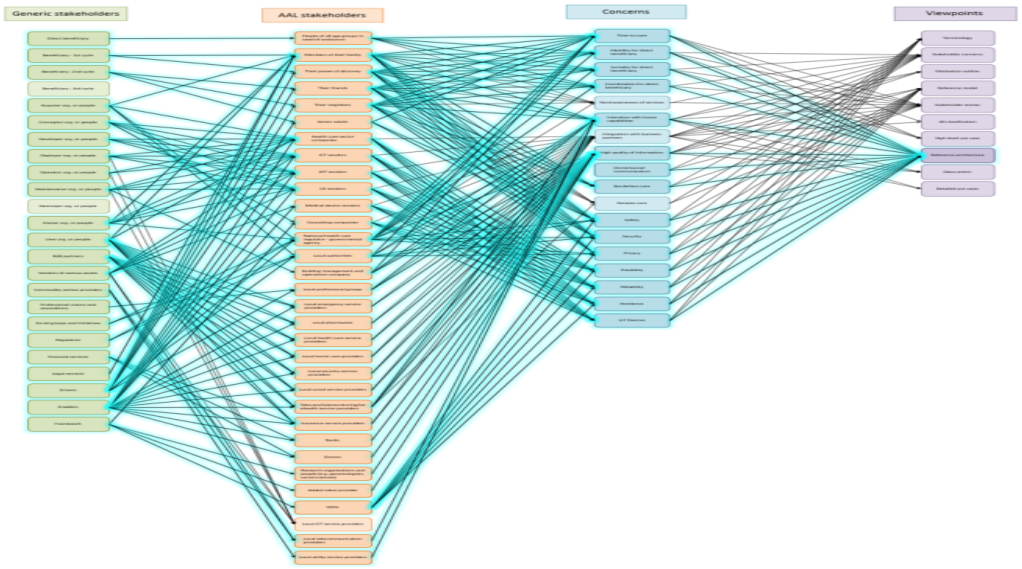
Some other Viewpoints

- Organizational Viewpoint
- Operational Viewpoint
- Implementation Viewpoint
- Deployment Viewpoint
- Compliance Viewpoint
- Regulations Viewpoint
- Risk Viewpoint
- Security and Safety Viewpoint
- Privacy Viewpoint
- Reliability and Resilience Viewpoint
- Governance Viewpoint

A few illustrations:

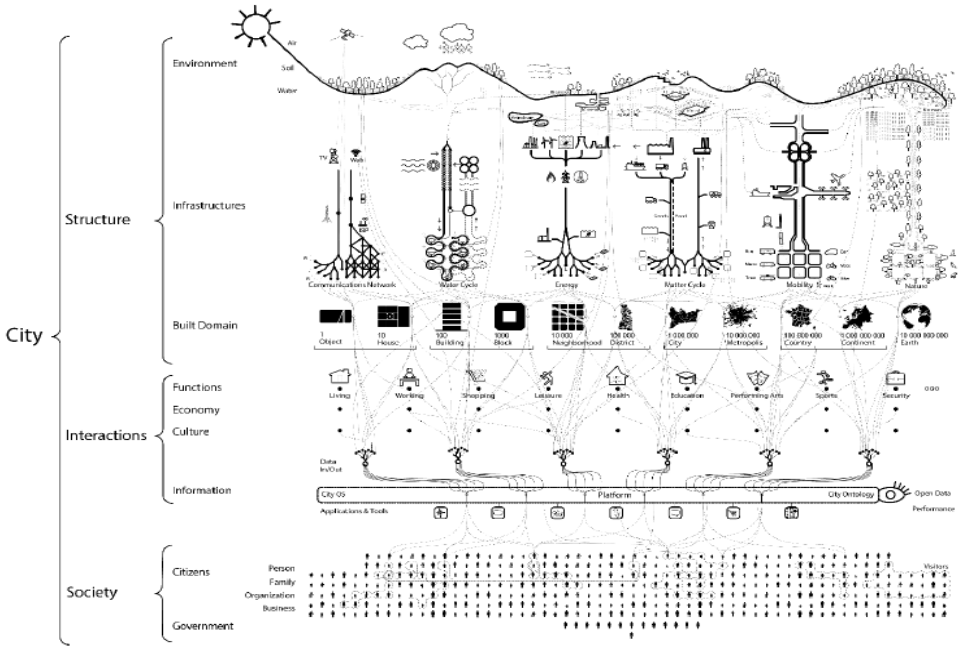
Motivation viewpoint

The motivation viewpoint is about linking various stakeholders (persons, groups of persons and organisations), their roles in Smart Cities (beneficiaries, regulators, etc.) and their concerns. Any City governance agency and all other stakeholders can use this viewpoint to build and to monitor an objective understanding of various and contradictory concerns around their city.



The Big Picture:

The big picture viewpoint is an idealised decomposition of the city's functionality into several areas. This viewpoint is necessary to establish a common-agreed view on Smart Cities as a system.

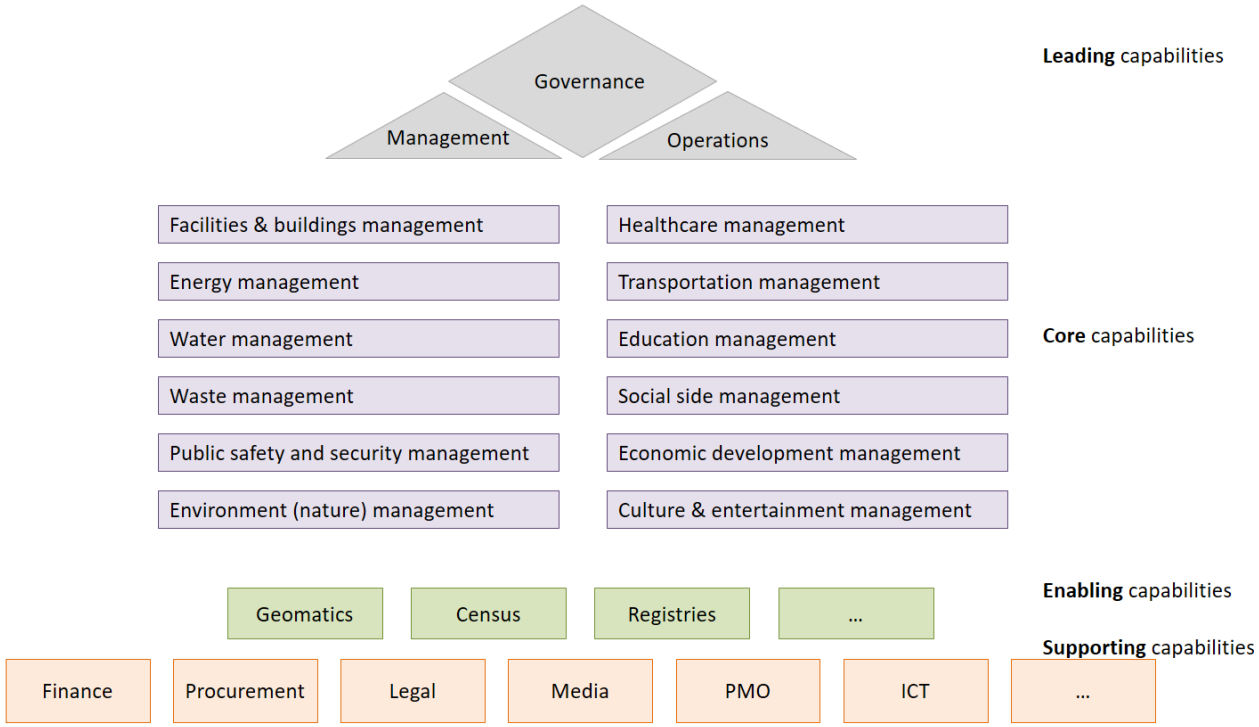


Taken from the Descriptive Framework for Cities and Communities being standardized by ISO TC 268

Capability Map

The Smart Cities capability map lists all capabilities (abilities to do something) of Smart Cities. Any City governance organ can use this viewpoint to

- ⇨ Analyze a comprehensive and well-structured set of capabilities
- ⇨ Benchmark the particular city via the maturity levels of its capabilities (also known as "heat map")
- ⇨ Take an informed decision about each capability (dependent on the unique situation of the particular city) either
  - To implement it at a particular level of maturity
  - To obtain it from business-to-business partners (outsource or insource)
  - To obtain it from commodity markets
  - To ignore it for now
  - To develop an implementation plan and monitor its implementation



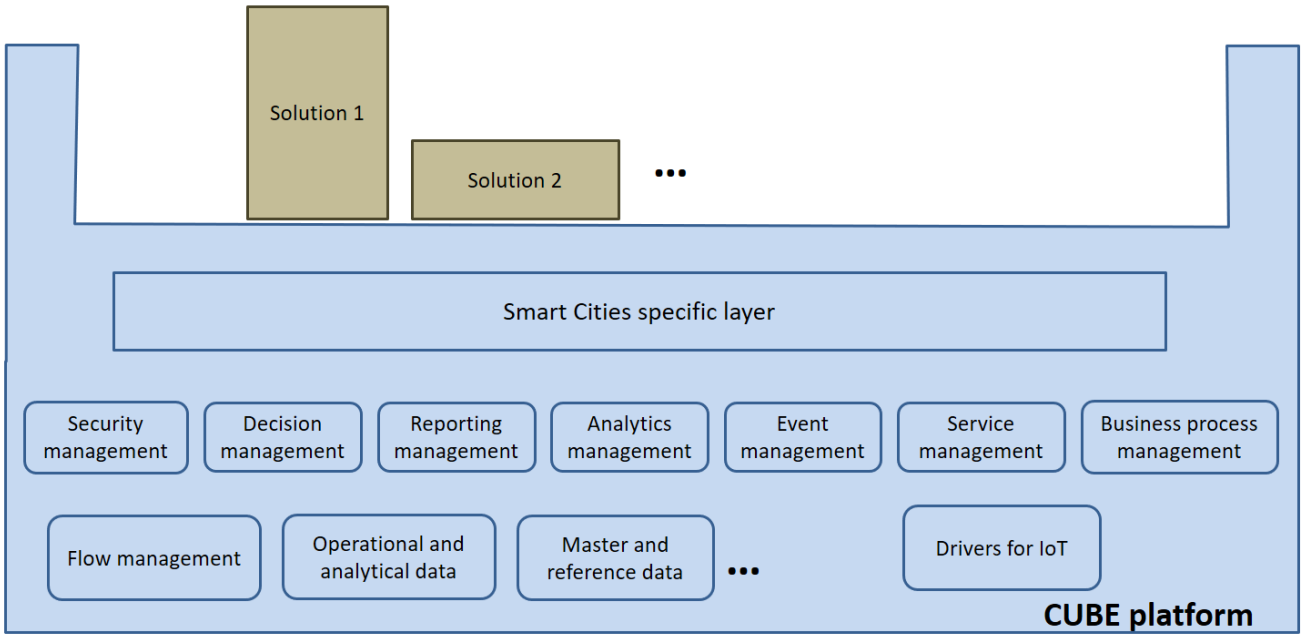
Implementation Viewpoint: Platform-based Implementation

The Smart Cities platform-based implementation viewpoint explains how to achieve collaboration and coordination among many Smart City programmes and projects. This viewpoint uses the "platform-enabled agile solutions" architecture pattern, which is based on the following considerations:

- ⇨ The platform must standardize and simplify essential capabilities of a system. For any capabilities outside the platform, new opportunities should be explored using agile principles.
- ⇨ These twin approaches should be mutually reinforcing: the platform frees up resource to focus on new opportunities while successful agile innovations are rapidly scaled up when incorporated into the platform.

- ⇨ To minimize duplication of effort in solving the same problems, there needs to be system-wide transparency and coordination of agile initiatives.
- ⇨ Existing elements of the platform also need periodic challenge. Transparency, publishing feedback and the results of experiments openly, will help to keep the pressure on the platform for continual improvement as well as for short-term cost savings.

Thus, the Smart Cities platform-based implementation viewpoint proposes a City Unified Business Execution (CUBE) platform. Using this platform, each Smart City can expedite its implementation by coordinating, collaborating and sharing the CUBE platform building blocks.



It implies that each Smart City uses its own "copy" of the CUBE platform, which is built from standard, commercial or open source, off-the-shelf and specific-for-a-particular-city building blocks (or tools). By starting small, any Smart City can build-up its own platform incrementally by using building blocks developed in from other Smart Cities programme and projects.

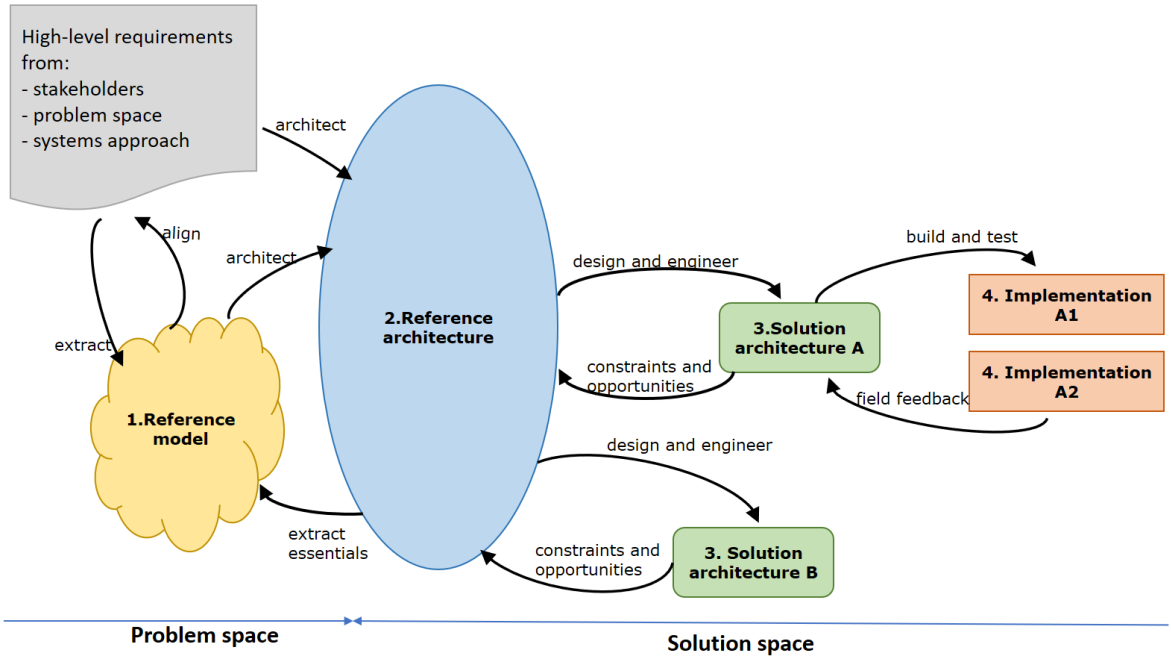
Four levels of Architecting

If the future solutions are rather complex, then it is recommended to use the following four levels of architecting:

- ⇨ Reference Model is an abstract framework for understanding concepts and relationships between them in a particular problem space (actually, this is terminology).
- ⇨ Reference Architecture is a template for potential solution architectures, which realizes a predefined set of requirements.
  Note: Reference architecture uses its reference model (as the next higher level of abstraction) and provides a common (architectural) vision, a modularization and the logic behind the architectural decisions taken.

- ⇨ Solution Architecture - is architecture of the future system
  Note: A Solution Architecture (also known as a blueprint) can be a tailored version of a particular reference architecture (which is the next higher level of abstraction).
- ⇨ Implementation is a realisation of the future system.

The dependencies between these 4 levels are shown in illustration below:

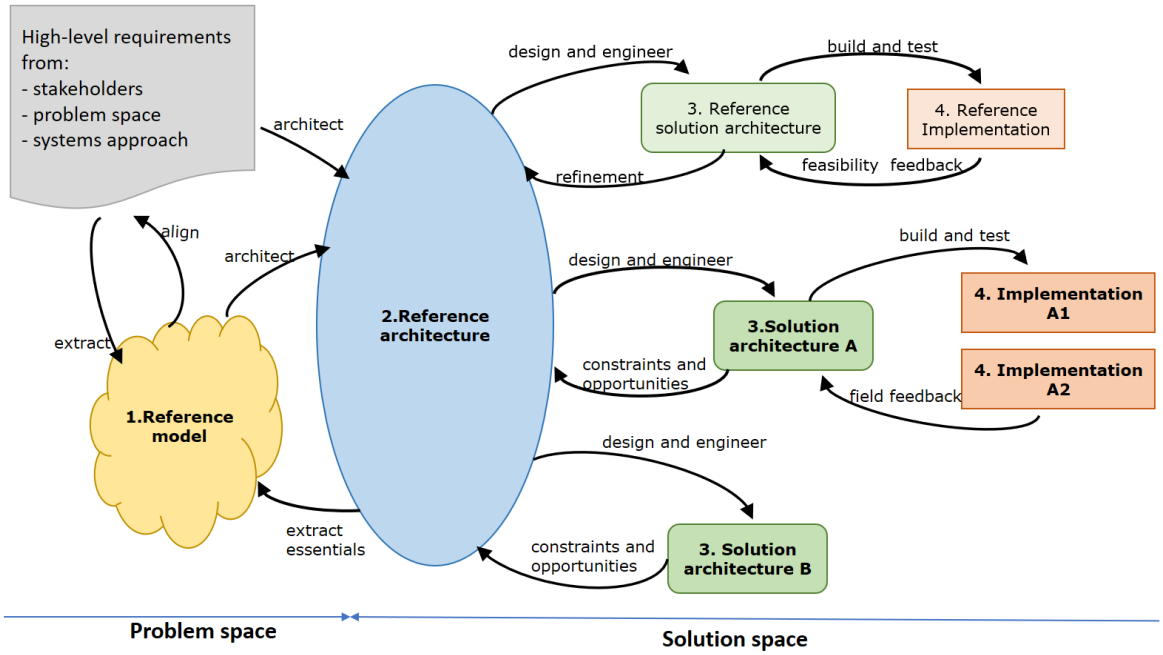


The presence of some "loops" of this illustration confirms the complexity of architecting. For example, there is no guarantee that the original high-level requirements have a high quality content, e.g. based on a prefect terminology; thus collecting of important concepts in the reference model may necessitate some modifications in the high-level requirements to align their terminology.

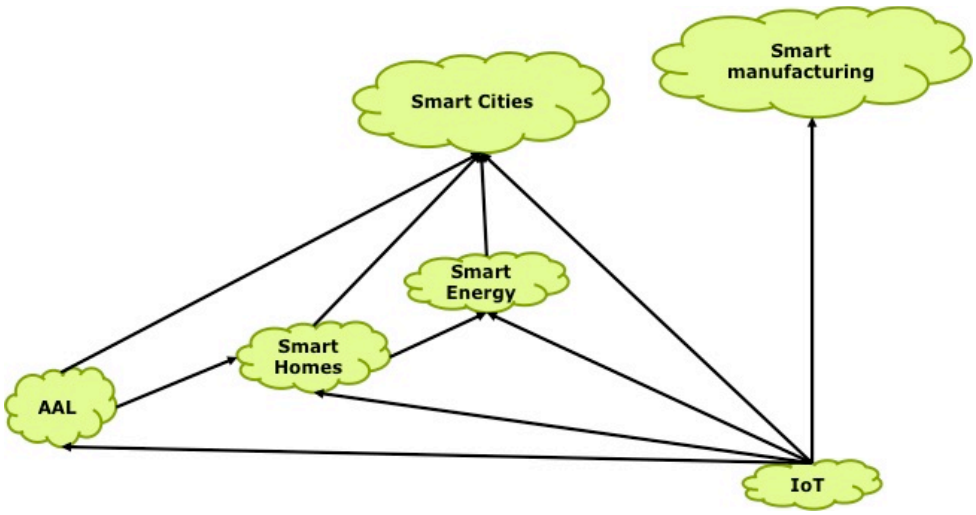
The purpose of the reference architecture is the following:

- ⇨ Explain to any stakeholder how future implementations (which are based on the reference architecture) can address his/her requirements and change his/her personal, professional and social life for the better; for example, via an explicitly link between stakeholders' high-level requirements and the principles of reference architecture.
- ⇨ Provide a common methodology for architecting the system-of-interest in the particular problem space, thus different people in similar situations find similar artifacts or propose innovations.

In case of the "very complex systems" to be implemented in several projects and the necessity to collaborate and coordinate between those projects, it is recommended to develop a reference solution architecture and, if required, a reference implementation (see illustration below). It helps to identify smaller systems elements (e.g. services, data, etc.) and relationships between them (e.g. interfaces) thus they can be shared between projects.



The reference solution architecture and the reference implementation are often experimental prototypes, which are not production quality.



The reference model is approximately covered by the value view. The reference architecture is approximately covered by the value view, big picture view and some models (primarily describing management frameworks) from other views.

More information about the IEC Systems Approach is available at https://resources.iec.ch/display/SRG/Welcome+to+IEC+SRG
The IEC Systems Approach digital working products
The IEC Systems Approach terminology
See https://resources.iec.ch/display/SRGTerminology/Systems+Approach+terminology
The IEC Systems Approach systems roles nomenclature
See https://resources.iec.ch/display/SRGTerminology/beneficiary

Study - PART 1 Section 1

Understanding

Global & National

Smart Cities Initiatives

&

Standardization Scenario

Global Initiatives: Smart City & Smart City Standardization

Global Smart City Standardization Imperatives & Initiatives:

Governments worldwide are driving smart cities in order to achieve their policies on energy efficiency, sustainable development and reliable, resilient and cost-effective infrastructure & citizen services for the whole community. Billions of Dollars and Euros are provided for research, development and deployment of smart city solutions. For a wide spread cost - effective deployment, interoperability and 'open interfaces for future extensions' standardized solutions are a necessity. Governments therefore also drive smart cities standardization, worldwide.

Over recent years there has been a major worldwide push towards smart cities with many major world cities rolling out initiatives and new services aimed at improving cities and the lives of citizens. Partly driven by this rollout, international and national standards bodies have begun to identify and propose standards for activities and technologies associated with smart cities. However, because the breadth and range of activities under the smart city umbrella is so large – from smart city performance indicators to water pipes, from transportation to open data, the range and breadth of the standardization activities is equally as large and can be quite daunting.

The 21st century is one of rapid urbanization. Ensuring that the world's cities offer citizens a rich and rewarding lifestyle requires that cities exploit technology to enrich people's lives, deliver services, and ensure sustainable growth. The breadth and scope of this task touches on many areas, and requires a holistic approach that not only looks at core technical issues, but also needs to consider the management, process, and strategies associated with smart cities. As always, standards play a key role in facilitating the adoption of new technologies and are critical to the growth of smart cities worldwide.

Standards-development organizations (SDOs) are busy mapping the Imperatives for standardization in the Smart Cities & Smart Infrastructure Domain including IEC, ISO, ITU, IEEE, IETF along with 3gpp, oneM2M and other regional & National SDOs like ETSI, CEN, CENELEC, NIST, BSI, DKE, DIN, JSA & BIS. Furthermore many standardization bodies and industry fora from the ICT and infrastructure industry consider Smart City as a priority issue. All the Global SDOs, Industry Consortia and Fora have been addressing the development of Reference Frameworks, Architectures & standards in this domain.

The benefits of Standards to Smart and Sustainable cities and communities

Most of the city planners and SDOs agree that standards could help by:

- ⇨ Enabling integration between systems, and between the physical and the digital Underpinning common understanding
- ⇨ Helping to obtain funding, and to prevent vendor lock-in
- ⇨ Enabling scale
- ⇨ Standards on physical and digital environments that ensure accessibility for all citizens.

It is well accepted that the development of relevant standards will help to deliver a smarter City in following ways:

- ⇨ Developing and managing an overall SSCC strategy
- ⇨ Implementing and managing major SSCC projects,
- ⇨ Doing things smarter
- ⇨ Putting in place a solid foundation.

Developing and Managing a Smart/Sustainable City Strategy:

Smart cities offer opportunities for integrated thinking and planning. The development of an overall smart/sustainable-city/community strategy is attractive for local authorities seeking to make best use of the available technologies. The use of standards is essential to enable a strategy to be drawn up, and to ensure the different city services can operate correctly in line with it. The focus is on the sort of guidance and standards that would help a city in developing and managing its overall smart/sustainable-city/community strategy.

The role of standards here shall be to:

- ⇨ Ensure that there is a common understanding amongst all the stakeholders of what makes the city into a smart one,
- ⇨ Provide with relevant and consistent guidance to integrating the different city services
- ⇨ To help with indicators to measure how well a city is doing overall
- ⇨ To help manage overall city resilience, industrial regeneration and other key citywide issues.

Implementing major new Smart/Sustainable City Projects

The implementation of major new smart sustainable city projects presents many key challenges. They are often cross-cutting – needing joint investment procurement and management by a variety of agencies within the city that may not be used to working together. They tend to be transformational in nature, requiring completely new ways of working by those agencies involved. They are also new and pioneering and it can be difficult to get the evidence needed to support the investment required.

Standards can help here in a number of ways. They can help with:

- ⇨ Improving Assessment and Funding of Smart/sustainable City Initiatives: with common agreed references and tools for stakeholders,
- ⇨ Improving and facilitating Procurement especially of these tailor-made solutions adapted to different circumstances.
- ⇨ Supporting the take-up of new practices for industry
- ⇨ Supporting the implementation of new infrastructure/equipment platforms; standards can contribute to lowering investments costs, facilitating integration with existing infrastructure and controlling operational costs.

Doing Things Smarter

- ⇨ Widening out sector specific standards: existing best practice in individual organisations and systems can be built on to provide city-wide best practice.
- ⇨ Through Data sharing with the support of key standards, for concept model, technical data to be stored and aggregated, effective data exploiting.
- ⇨ With planning Guidelines based on standards, to ensure that developments and infrastructure projects are designed and built in a way that facilitates the city's progress towards becoming smarter.

- ⇨ With urban modelling tools as guidance document for city/community leaders and planners to help them understand how best to utilize these new tools.
- ⇨ Through Skills and Education, an important item even critical to smart cities development that should be addressed taking into account all the above issues.
- ⇨ Facilitating financing projects as for example use of energy saving performance contracts (ESPCs), long term concession-based contracts or public private partnership (PPP) and new business models are today being used or under development.

Putting in place a solid foundation for

- ⇨ Smart cities for all citizens needs: standards programmes, necessarily taking an overall approach, can redress the balance and include, ensure that citizen needs are covered.
- ⇨ Legal issues and ethics: "Big data" in a smart/sustainable-city/community environment raises issues that urgently need to be addressed. Central legislation - supported by proper standards on the technical implementation of personal data protection and privacy - should help reduce these problems.
- ⇨ Supporting Inclusivity and Accessibility: Standards for Accessibility and Active Assisted Living are critical to ensure the Smart Cities/Infrastructure Design considers these issues while designing.

India Perspective for Smart Infrastructure:

However, the perspective of Smart Cities is a little different in the Developed Nations from the Developing Nations like India. Smart City paradigm is about integration of all the utilities, infrastructure and citizen services on a single platform and unified dashboard for efficient, reliable n resilient operation of the city. In developed nations, when they started discussing the Smart City Paradigm, most of their respective utilities were already smart with their respective albeit Silo'd platforms and dashboards. Hence, what they needed was to just build/create another layer of IT Platform & dashboard to get all the data on this common platform and providing a unified, comprehensive and user friendly view of the O & M of the whole city… in India, in spite of our intensive efforts in last two decades to bring automation in our various utilities and infrastructures, none of our utilities are till date truly smart. Hence, we have an opportunity to look at the Smart Infrastructure Design with a fresh perspective that shall be rather more relevant in the coming decades.

Categorizing Standardization Activities

The amount of activity in smart city standardization is truly broad and covers many areas. Some groups, such as IEEE, are looking at detailed technology aspects related to smart city networking or transportation while others, such as the International Organization for Standards (ISO), have a focus on higher-level activities such as strategies for smart city governance or procurement. A useful way to categorize these different types of standardization activities is to group them by level of abstraction into strategic, process, and technical. (See the BSI's PD 8100 smart city overview for more details.)

Level 1: Strategic. These are smart city standards that aim to provide guidance to city leadership and other bodies on the "process of developing a clear and effective overall smart city strategy." They include guidance in identifying priorities, how to develop a

roadmap for implementation, and how to effectively monitor and evaluate progress along the roadmap.

Level 2: Process. Standards in this category are focused on procuring and managing smart city projects–particularly those that cross both organizations and sectors. Essentially these offer best practices and associated guidelines.

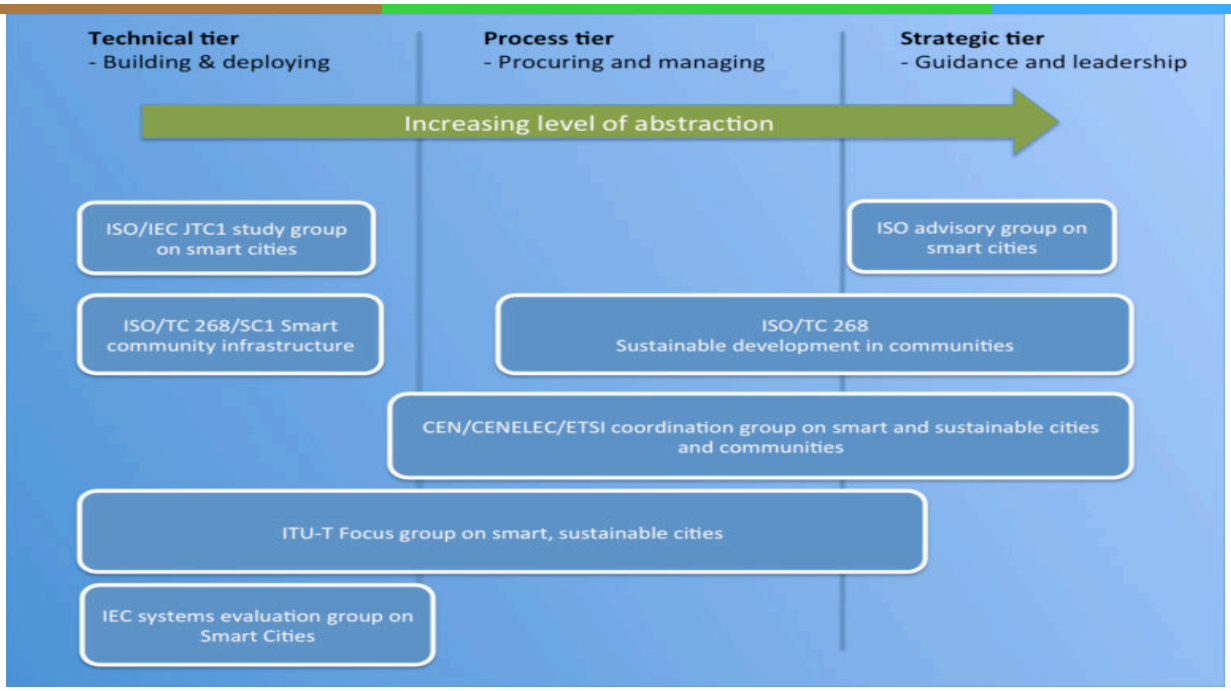
Level 3: **Technical**. This level covers the myriad technical specifications that are needed to actually implement smart city products and services so that they meet the overall objectives As stated in the BSI PD 8100: "Strategic-level standards are of most relevance to city leadership and process-level standards to people in management posts. However, even technical specifications are relevant to people in management posts, as they need to know which standards they need to refer to when procuring technical products and services."

Using the Framework to Position and Group Standards Activities

Using this three-tier framework, it is possible to place many of the major international standards activities to better understand where their focus lies. The major international groups that have smart city activities include:

- ⇨ **ISO:** International Organization for Standards is the main global body that national standards bodies work with and which many of us are familiar with via "ISO certified". ISO has set up a strategy advisory group (SAG) for smart cities which is helping coordinate ISO activities and has been instrumental in helping in the formation of Technical Committee 268, which is developing standards across all three tiers.
- ⇨ **IEC:** Founded in 1906, the IEC (International Electrotechnical Commission) is an established organization for the preparation and publication of international standards for all electrical, electronic, and related technologies, known collectively as "Electrotechnology." The IEC has a joint technical group with the ISO looking at smart cities, and its own Systems Committee on smart cities.
- ⇨ **ITU:** The International Telecommunication Union is the United Nations' specialized agency for information and communication technologies – It created a focus group on smart sustainable cities (FG-SSC) that delivered a series of technical reports. A follow-on group, Study Group 20, is continuing that work.
- ⇨ **CEN/CENELEC/ETSI:** In Europe, standards are developed and agreed to by the three officially recognized European standardization organizations: the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the European Telecommunications Standards Institute (ETSI). These groups have set up a coordination group focused on smart and sustainable cities and communities.

The Figure below places these groups graphically and identifies which subgroups are active in each of the three tiers:



International standards activities and their respective foci

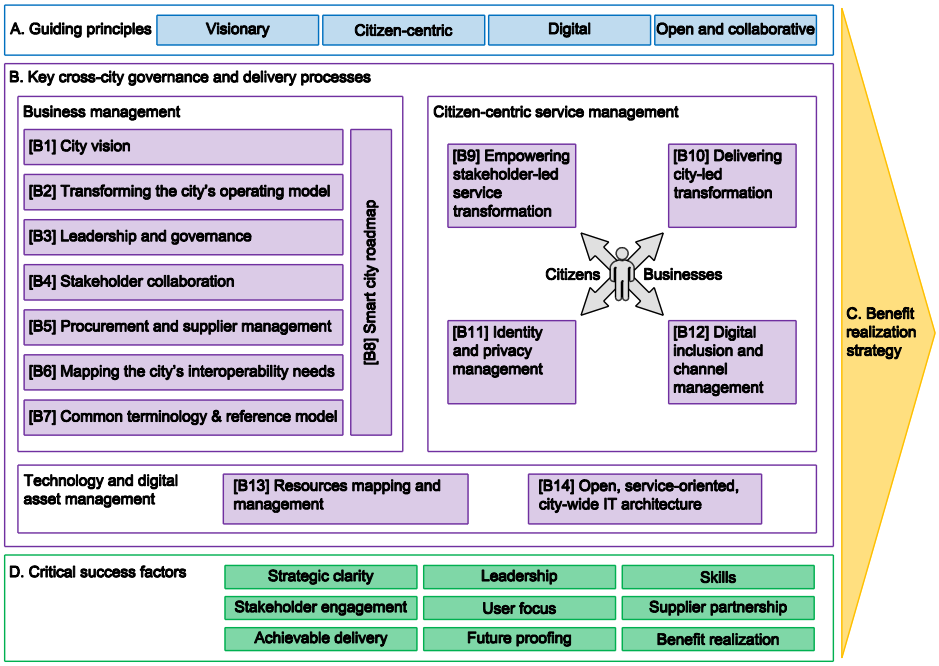
Looking at the output from some of these groups, we can now identify ongoing activities or standards and place them into the appropriate categories

STRATEGIC–Aimed at the Process of Developing a Clear and Effective Overall Smart City Strategy

- ***ISO 37120***, Sustainable Development of Communities–Indicators for city services and quality of life. This standard, part of a suite by ISO's Technical Committee 268 (TC 268), identifies 100 indicators that cities should track to allow them to benchmark progress. Actually, there are 17 areas, 46 core and 54 supporting indicators that cities either "shall" (core) or "should" (supporting) track and report. The World Council on City Data has been set up by cities to benchmark cities, has certified 17 global cities, and is a good place to see this standard in use.
- Two ***draft*** ISO standards, also from TC 268, but looking very much at management and strategy, are **ISO 37101**, Sustainable development and resilience of communities–Management systems–General principles and requirements; and **ISO 37102**, Sustainable development and resilience of communities– An overview of this ongoing project can be found on the ISO's website.
- ISO/TR 37150 - Smart community infrastructures — Review of existing activities relevant to metrics
- ISO/TS 37151 – Harmonized metrics for benchmarking smartness of infrastructures
- ISO 37152 - Smart community infrastructures — Common framework for development and operation
- Although not an international organization, the BSI's **BS 8904** has a focus on sustainable communities and "provides a framework for recommendations and guidance that assist communities to improve. The recommendations and guidance can be applied by communities of any size, structure, and type."

PROCESS: Procuring and Managing Smart City Projects

- ⇨ The development by the BSI of a smart city framework standard (PAS 181) falls into the process category. "It provides practical, "how-to" advice, reflecting current good practice as identified by a broad range of public, private, and voluntary sector practitioners engaged in facilitating UK smart cities."
- ⇨ Related to PAS 181 is the development of a data concept model for smart cities (PAS 182). This is an interesting activity, as a data model is critical for the development of smart city data hubs and data interoperability issues that are key components of any open data strategy.



TECHNICAL: Implementing Smart City Projects

- ⇨ A useful overview of the technical activities of the ISO, IEC, and ITU can be found in a report from the ISO/IEC JTC1–Preliminary Report on Smart Cities. This document lays out the smart city space from a technical point of view with a good overview of the technical areas that the ISO, IEC, and ITU are working on, as well as details of their standards work and of the overall activities of JTC1.
- ⇨ IEC Systems Committee on Smart Cities is focusing on the Electrotechnical Aspects of Smart Cities. However before addressing the Electrotechnical aspects, it is developing – A reference Architecture Model & Standards Mapping Tool for Smart Cities.
- ⇨ Two technical standards from the ISO/IEC JTC1 group that are still under development are: ISO/IEC AWI 30145, Information technology–Smart city ICT reference framework, and the associated ISO/IEC AWI 30146, Information technology–Smart city ICT indicators, which are both looking at the ICT infrastructure needed for smart cities.

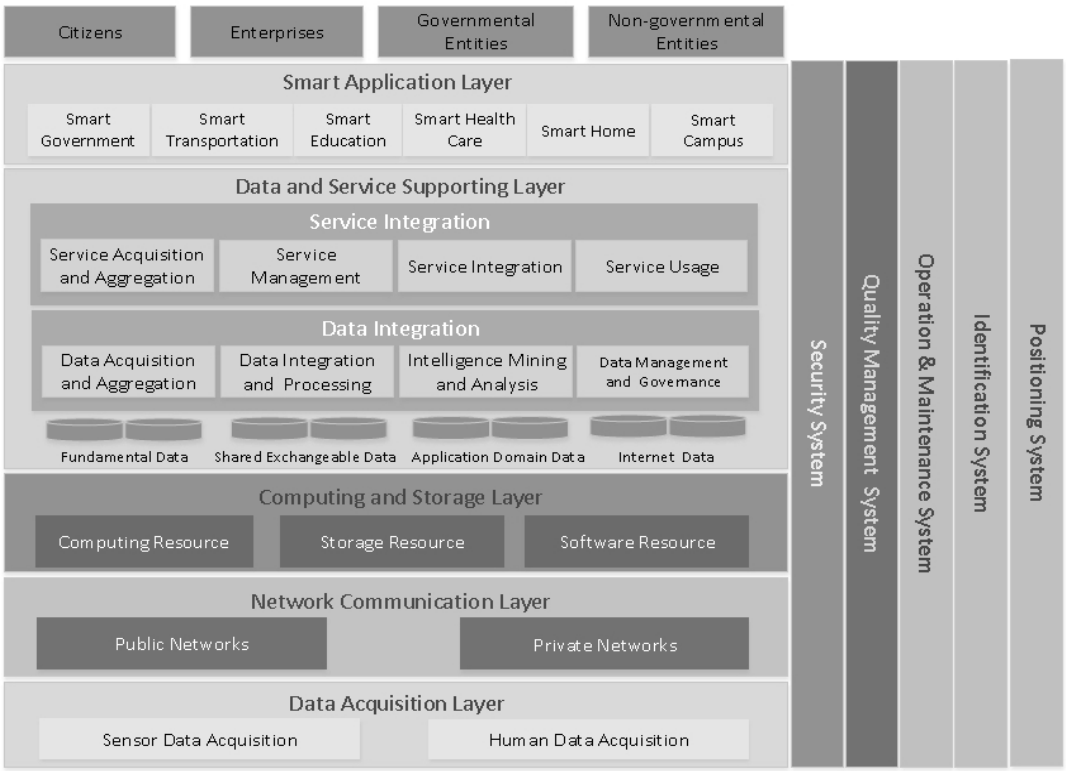
ISO/IEC 30145 currently being developed by the ISO/IEC-JTC1/WG11 on Smart Cities ICT addresses the following three aspects of the Smart City ICT Reference Framework:

- Part 1: Business Process Framework
- Part 2: Knowledge Management Framework &
- Part 3: Engineering Framework...

These three views are each aimed at a different role or viewpoint within the city and thus separate focus needs to be maintained. The "separation of concerns" is a principle for development of system architecture as a set of views. The value of using the separation of concerns is to simplify development and maintenance of the architecture.

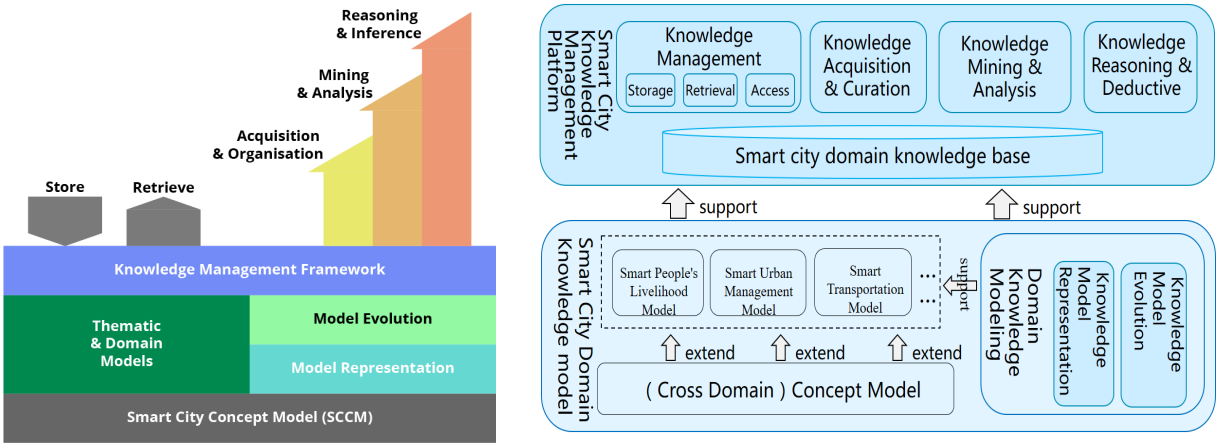
ISO/IEC 30145 – Part 1 Smart City Business Process Framework –

Considering that a smart city can be described, at a high level, simply in terms of the transformational business processes that ICT enables so that the city functions more effectively for the benefit of its residents. The Business Process Framework is meant to describe and categorize those processes. The objectives of the Business Process Framework are to - Create a common language for use across departments, systems, external partners and suppliers, reducing cost and risk of system implementation, integration and procurement; and - Adopt a standard structure, terminology and classification scheme for business processes to simplify internal operations and maximize opportunities to partner within and across industries.



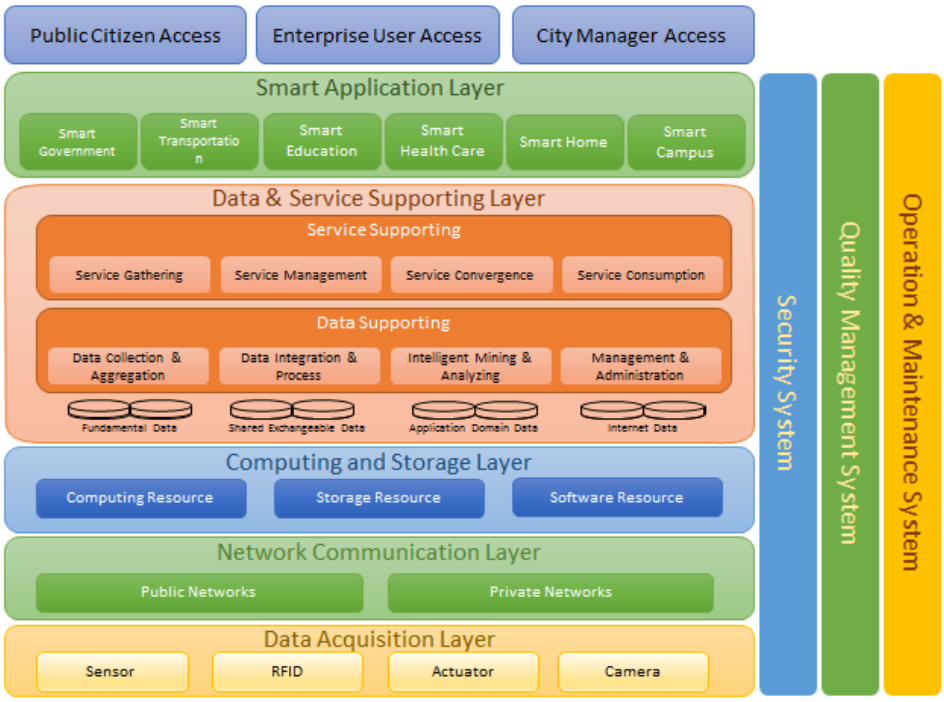
ISO/IEC 30145 – Part 2 Smart City Knowledge Management Framework –

The Smart City Knowledge Management Framework is principally a tool for data managers within the key agencies within the city. It also addresses needs of service managers and strategic managers within the city, because it underpins and improves data and information sharing, collaboration and consultation. This standard will focus on smart city specific data and the key practices, which need to be implemented to ensure the interoperability of data within a smart city. The Knowledge Management Framework describes how data and knowledge needs to be managed in the city to enable the smart city business processes.



ISO/IEC 30145 – Part 3 Smart City Engineering Framework –

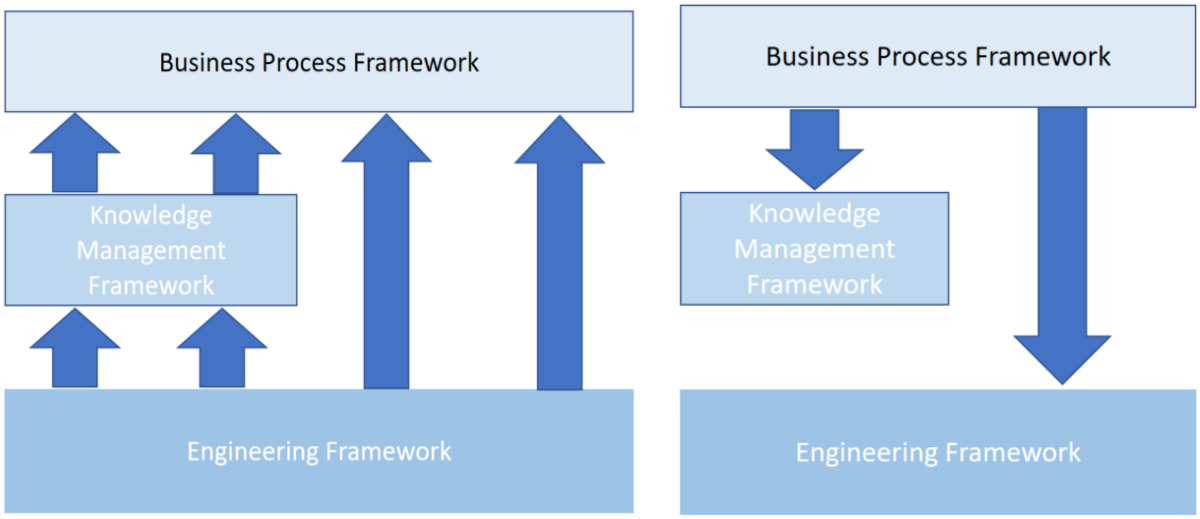
The purpose of the Smart City Engineering Framework is to guide the integration of common systems components with industry-specific components, and guide the creation of industry solutions for targeted customer problems within a particular industry. This Smart City Engineering View would respond to the business process needs identified in ISO 34015-Part 1 and implement the technology to exchange the knowledge elements identified in ISO 34015-Part 2.



The Figure above provides a common smart city engineering framework from ICT perspective. Taken compatibility and commonality into account, the framework consists of 5 horizontal layers and 3 vertical cross layer systems with 3 types of city users. Five layers are data acquisition layer, network communication layer, computing and storage layer, data and service supporting layer and smart application layer. Three systems are security system,

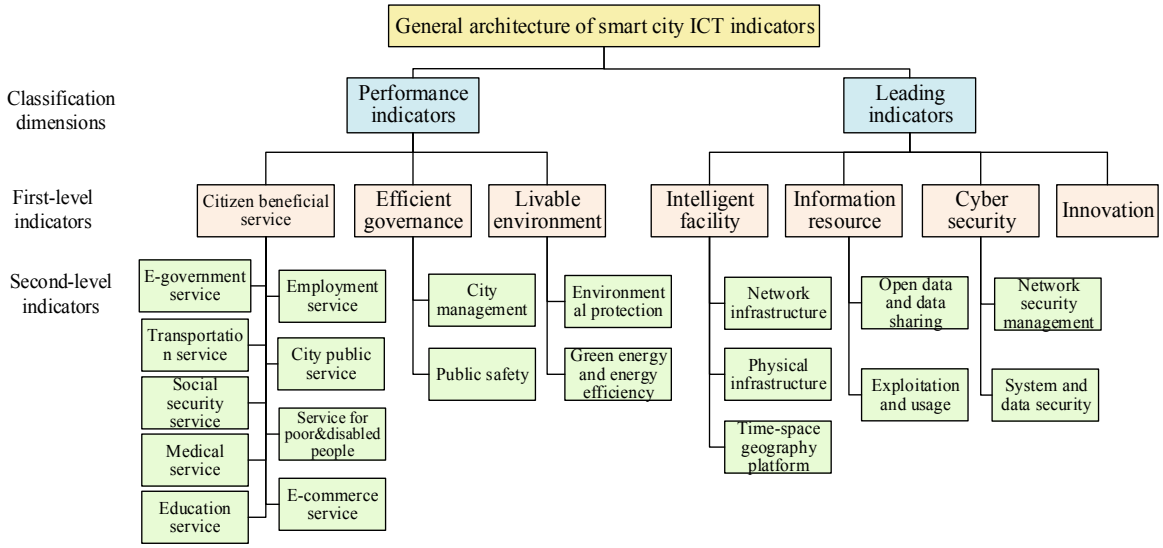
quality management system and operation & management system. Three types of city users are public citizen, enterprise and city manager.

The relationship amongst the ISO 30145 Three Frameworks:



ISO/IEC 30146 – Smart City ICT Indicators

This document defines a comprehensive set of evaluation indicators specially related to ICT adoption and usage in smart cities. Firstly, this document establishes an overall framework for all the indicators. Then, this document specifies the name, description, classification and measure method for each indicator.



General Architecture of Smart City ICT Indicators

IEC – Systems Committee Smart Cities:

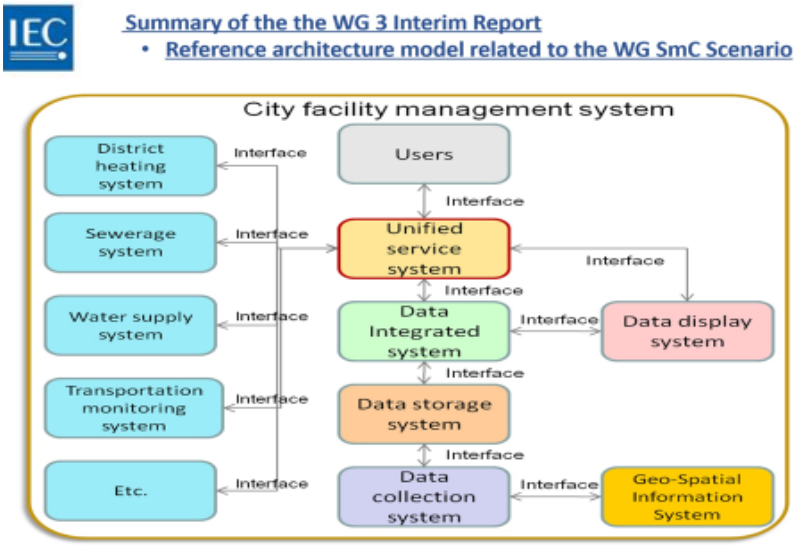
Based on the recommendations of the Systems Evaluation Group SEG1 Smart Cities, SyC Smart Cities established the following three working groups (WG):

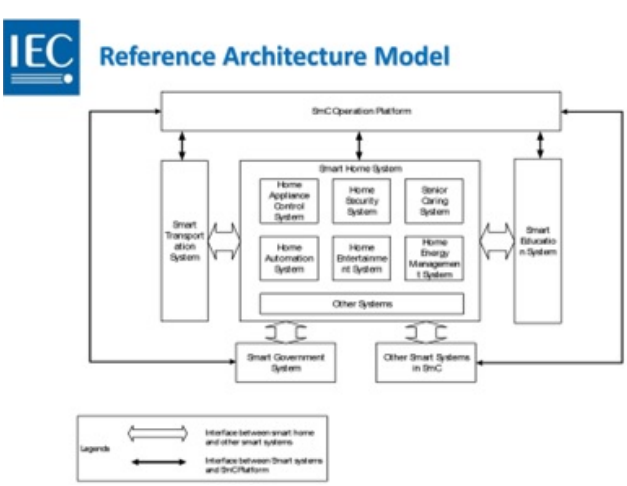
⇨ **WG 1: Terminology** – To Develop and maintain a common set of terminology for the SyC

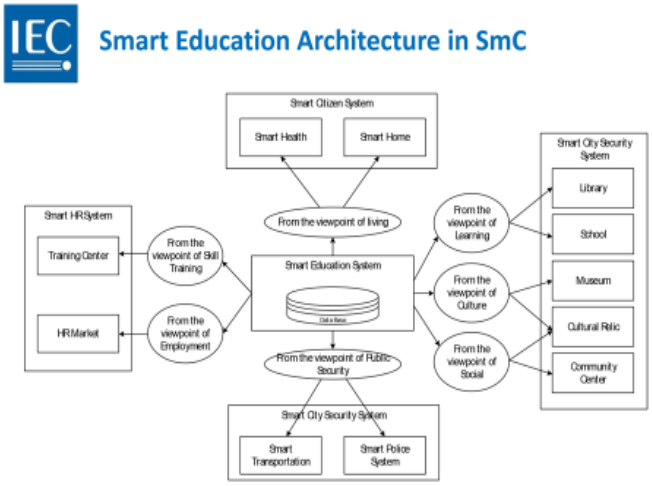
- ⇨ **WG 2: Market Relationship** –
  - To Identify the key aspects of a Smart City
  - Collect and analyze use cases
  - Electrotechnical aspect of smart cities simulation
  - Road test standards in real cities
- ⇨ **WG 3: Reference Architecture** – To Develop and maintain reference architecture model and standards mapping tool for smart cities in collaboration with the IEC Systems Resource Group (SRG)

During the SEG1 preliminary work, IEC emphasized that the reference architecture needs to be built in such a way as to enable all of the different views depicted in these different models identified in the Appendix to be built up from it, so that it will provide a way of linking them together in a coherent way.

And, three of the Work Groups developed models or reference architectures related to their own specific views of the city. These reference architectures show the key systems and the important interfaces within them that are covered by the specific scope of the particular working group.







After the establishment of the Systems Committee, WG3 Reference Architecture reviewed the plethora of Reference Architectures and Models developed, and still being developed by different SDOs and stakeholders of the Smart Cities ecosystem. Based on the Study, it was decided that IEC must develop a comprehensive and all-inclusive Reference Framework comprising of Reference Architectures with multiple Views but common underlying coherent foundation linking all the diverse domain centric viewpoints of the Smart City Reference Architecture. Further, it was decided to define a "Smart Cities Reference Architecture Methodology" to help all the SDOs and other stakeholders to develop Smart Cities Reference Architectures from their respective viewpoints also in a Structured manner.

Hence, as a first step the IEC SyC Smart Cities has started work on Two Strategic yet Foundation Standards – One on "Smart Cities Reference Architecture Methodology" and second on "Smart Cities Reference Architecture" with multiple viewpoints.

ITU - Information and communications architecture for smart city

As per document published by ITU entitled "Setting the framework for an ICT architecture of a smart sustainable city", the information and communication architecture should be seen from the following perspectives:

Physical information and communications perspective

In this document, only the information and communication architecture from the communications perspective is being highlighted. Figure shows a corresponding smart city information and communication architecture emphasizing on the communications perspective.

Sensing layer

This consists of terminal node and capillary network. Terminals (sensor, transducer, actuator, camera, RFID reader, barcode symbols, GPS tracker, etc.) sense the physical world. They provide the superior "environment-detecting" ability and intelligence for monitoring and controlling the physical infrastructure within the city.

The capillary network (including Supervisory Control and Data Acquisition (SCADA), sensor network, Highway Addressable Remote Transducer (HART), WPAN, video surveillance, RFID, GPS related network, etc.) connects various terminals to network layer, providing ubiquitous and omnipotent information and data.

Network layer

The network layer indicates various networks provided by telecommunication operators, as well as other metro networks provided by city stakeholders and/or enterprise private communication network.

Data and support layer

The data and support layer is fundamental in making the city "smarter", with its main purpose is to ensure the support capabilities of various city-level applications and services. Data and support layer contains data center from industries, departments, enterprises, as well as the municipal dynamic data center and data warehouse, among others, established for the realization of data process and application support.

Application layer

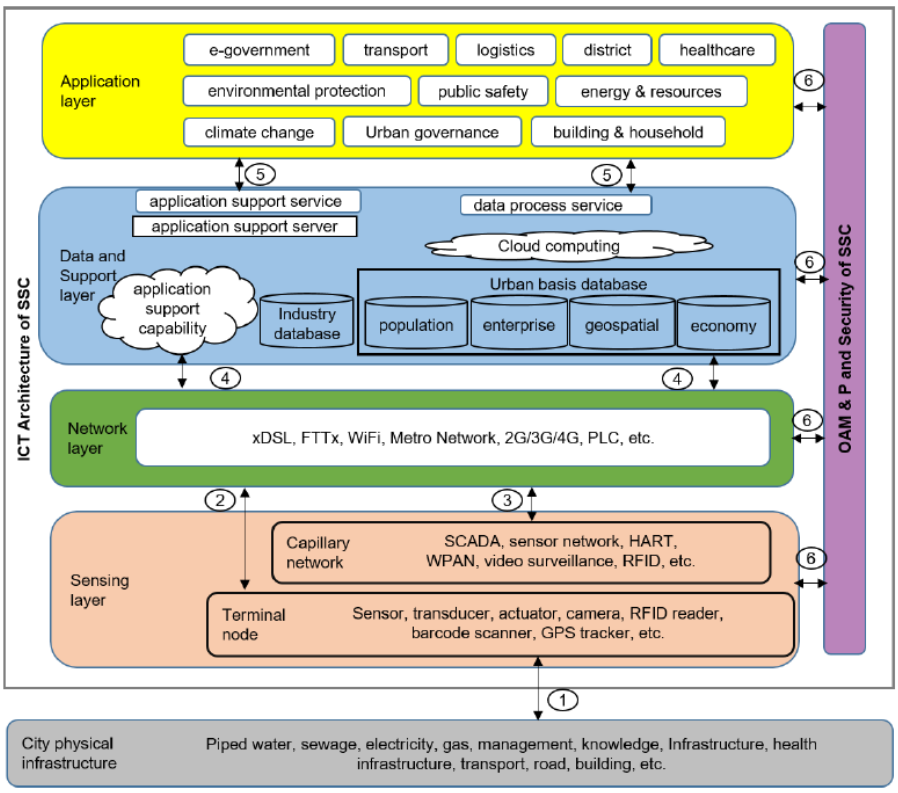
The application layer includes various applications that manage the smart city and deliver the smart city services.

Operation, Administration, Maintenance and Provisioning (OAM & P) and security

This provides the operation, administration, maintenance and provisioning, and security function for the information and communication systems of smart cities.

Interfaces between layers

Six interfaces between layers and OAM & P and security framework, marked with numbers in circles are shown in the figure below. These are places where communications and exchange of information between the layers, and OAM & P and security framework take place. They are the focal point of standards specifications and thus are called communication interface point.



Multi-tier smart cities information and communication architecture from communications view, emphasizing on a physical perspective

Overall functions at each of these reference points are as under:

Communication interface point 1

This exists between the city physical infrastructure and sensing layer. It enables the terminals sense the physical world, i.e. exchange of information and control signals between terminal nodes in sensing layer and the physical infrastructure.

Communication interface point 2

This exists between the terminal nodes in sensing layer and the network layer. In this case terminal nodes, directly or through net gates, access to the network layer without through capillary network.

Communication interface point 3

This exists between the capillary network in sensing layer and the network layer. In this case, capillary networks collect the sensing data, and connects to the communication networks

Communication interface point 4

This exists between the network layer and the data and support layer. It enables communications between data centers and lower layers for collecting all the information through the communication networks.

Communication interface point 5

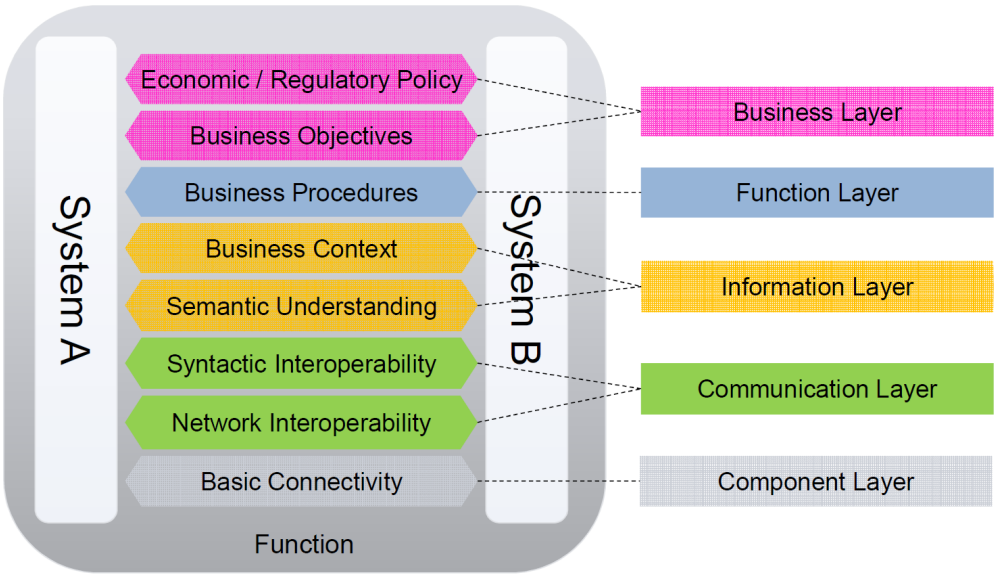
This point exists between the data and support layer and the application layer. It enables data centers and/or application support functionalities providing information to corresponding city applications and services, and also enables integrated applications exchanging data via data centers and/or application support functionalities.

Communication interface point 6

This exists between the OAM & P and security framework and the four layers. It enables the corresponding modules to exchange data flow and control flow and provide operation, administration, maintenance, provisioning and security function.

EU – CEN-CENELEC-ETSI Approach:

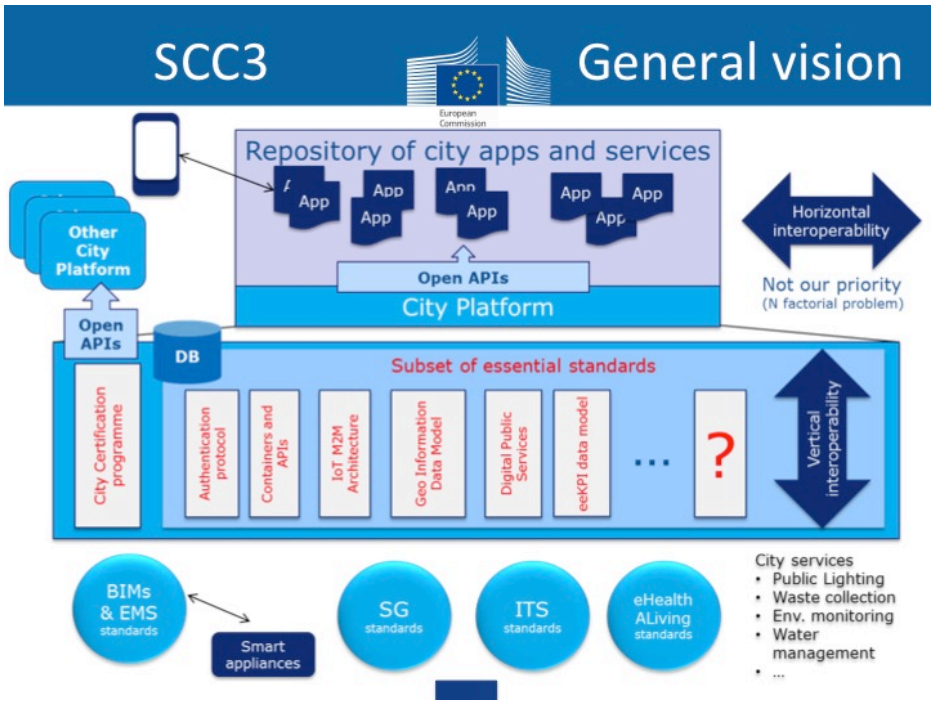
Smart and Sustainable Cities and Communities Coordination Group under European Union has made recommendation for all three layers/domains – Strategic, Processes & Technology. On the Technology aspects they describe Smart City as a model of the different layers that need to be considered when integrating two systems together:



European Union:

Smart Cities and Communities Programme under Horizon 2020

This programme is based on the basic assumption that Cities will, with all probability, provide an **Urban Platform** on which most City Applications and Services will run. This platform will be the main backbone for many existing sector systems (like Energy Efficient Buildings, Smart Grid, Intelligent Transport Systems, eHealth Systems) and many new applications and systems specifically designed for the City.



Smart Cities and Communities Urban platforms Experience from leading European cities

Project ESPRESSO EU

ESPRESSO (Espresso – systEmic standardisation apPRoach to Empower Smart citieS and cOmmunities) focuses on the development of a conceptual Smart City Information Framework based on open standards.

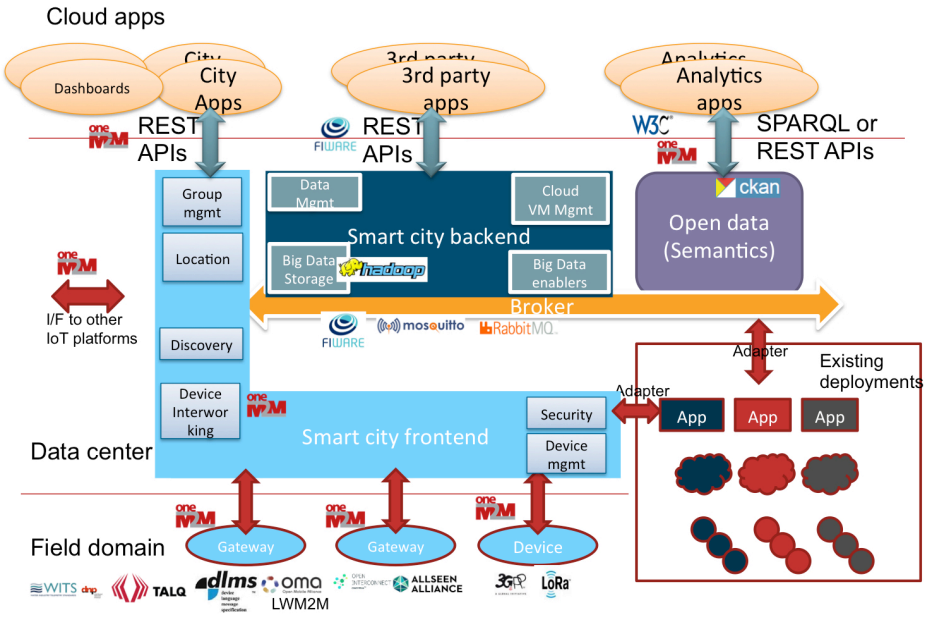
ESPRESSO wants to define the scope of the project by analyzing sectorial systems, defining use cases and test scenarios, and building a conceptual standardized interoperable framework by evaluating the current standards landscape including gap analysis, and design pilots, which will be used to run test scenarios with the project partner cities to make practical experiences with the currently available set of standards and technologies.

One of the key objectives of ESPRESSO is to identify a collection of open standards that work well together ("conceptual standards framework"), having been proven to help smart cities, and of course to identify gaps and weaknesses in the framework of available standards.

oneM2M:

oneM2M is the global standards initiative that covers requirements, architecture, API specifications, security solutions and interoperability for Machine-to-Machine and IoT technologies. oneM2M specifications provide a framework to support applications and services such as the smart grid, connected car, home automation, public safety, and health. The oneM2M framework, based on open standards and open API interfaces, enables city planners to sidestep 'vertical' rollouts that simply do not scale.

To meet these numerous requirements, oneM2M has developed horizontal platform architecture. oneM2M software is found in the M2M Common Services Layer (CSL), which sits below the M2M application layer and above the transport layer. The CSL middleware breaks down silos by enabling apps to share a common services platform.

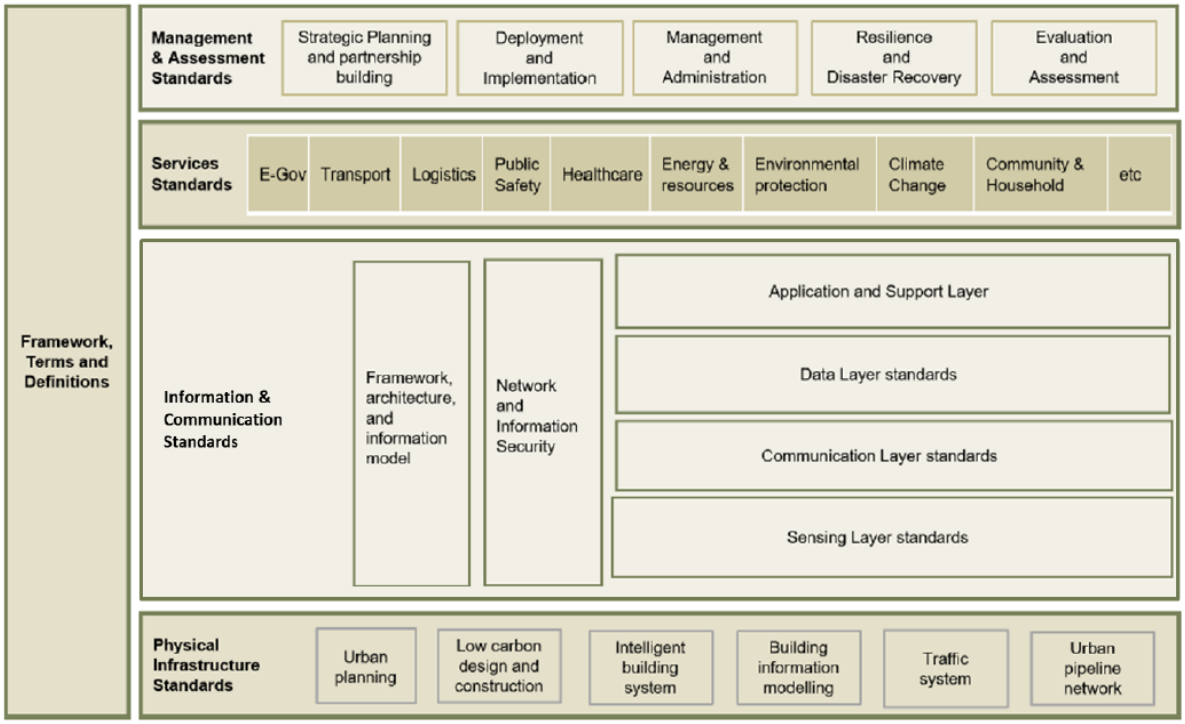


oneM2M specifications paved the way for devices to connect securely to apps residing in either the cloud or the gateway across a horizontal architecture. A library of Common Service Functions (CSF), which forms part of the CSL, enables connectivity. Functions include discovery and registration, as well as location and communication management. These functions can all be shared by multiple IoT applications, which is another cost-saving efficiency of the oneM2M horizontal architecture. There is no need for app-specific software, other than the application logic itself.

IEEE Standards

IEEE has a wide variety of standards and ongoing activities that relate to key technical areas of the future smart city. Generally IEEE standards, due to their nature, fall under the category of technical standardization. One of the most critical is **IEEE P2413**, which is a developing standard for an architectural framework for the Internet of Things (IoT). The standard is being designed to offer a reference model defining relationships among various IoT verticals critical to smart cities, such as transportation and healthcare, and their common architectural elements.

IEEE also has ongoing activities in smart buildings, security, and communications that are all relevant to smart cities. A more complete list of IEEE activities involving the smart city can be found in the regularly updated report IEEE Standards Activities for Smart Cities. In addition, IEEE maintains a smart city community website to help coordinate member activities in the smart city area, which provides regular updates on activities and conferences related to smart cities.



Smart City standardisation framework that is widely adopted by international standard development organisations

NIST –

IES City Framework – In an effort to lower the barriers to widespread deployment of effective and powerful smart city solutions, NIST and its partners have convened an international public working group to compare and distill a consensus language, taxonomy and framework of common architectural features to enable smart city solutions that meet the needs of modern communities.

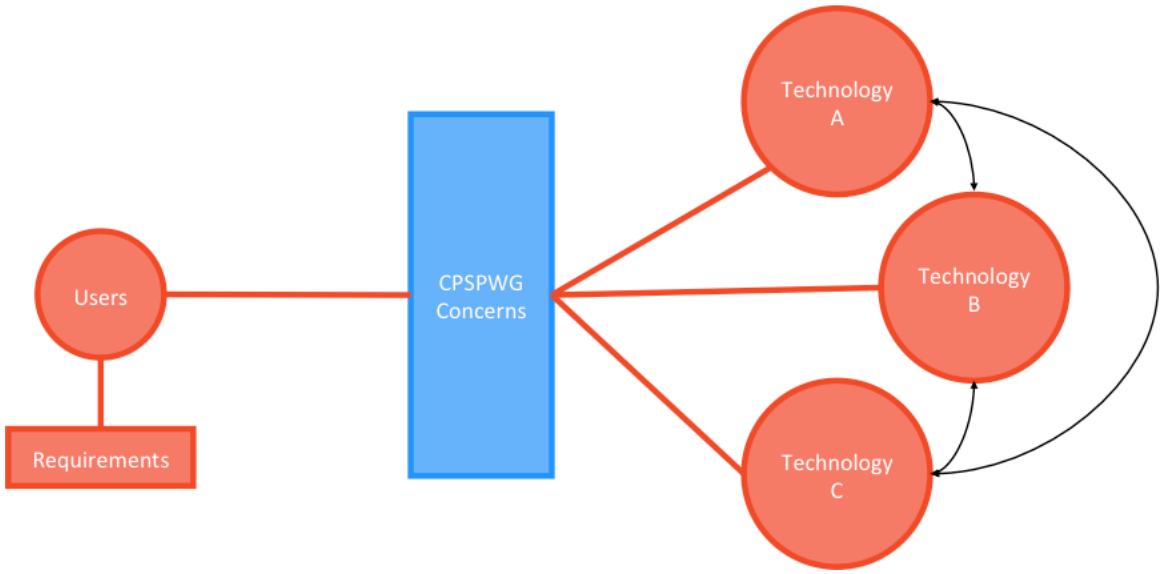
In May of 2015, NIST published the NIST_CPS Framework Release 1.0, which provides an analysis and technical framework for describing and analyzing CPS. This report represents the efforts over the course of two years of hundreds of participants from industry, academia, and government.
The new and salient aspects of design, construction, and operational challenges may be summarized as three project types:

- ⇨ A component(s) of a larger complex/interactive systems of systems while being composed of systems of systems;
- ⇨ Real-time hardware/software interactions that must bridge between internal and external systems to function successfully; and
- ⇨ Real-time human-machine-software interactions essential to meeting user goals and expectations.

CPS are complementary software/hardware systems of systems that are integral to ultra-large-scale systems and manifest all the differentiating characteristics of these emerging project types Per this NIST Cyber-Physical Systems Public Working Group initiative, it makes sense to focus on developing *a framework for creating smart cities cyber-physical systems data exchange protocols*. These standards will become the platform technologies upon which developing socio-technical systems, ultra-large-scale systems, and complex, large-scale, integrated, open systems will be based.

Applications vs. technologies – Smart Cities involve applications that are entire and include sets and subsets of interactions with the physical world, humans, enterprises, computation and storage all interconnected – sets of concerns – that can be composed in any permutation needed to achieve them.

The following figure is being considered as a model for the project deliverables with the Application Framework tools on the left and the Consensus PPI on the right and the Deployed PPI describing case studies of the two working together:



NIST - IES-City Framework Structure

Initiatives in INDIA:
Smart Cities & Smart Cities Standardization

The Government of India launched the Smart Cities Mission on 25 June 2015 with the objective to promote sustainable and inclusive cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions.

Some of the core infrastructure elements in a Smart City would include adequate water supply, assured electricity supply, sanitation, including solid waste management, efficient urban mobility and public transport, affordable housing, especially for the poor, robust IT connectivity and digitalization, good governance, especially e-Governance and citizen participation, sustainable environment, safety and security of citizens, particularly women, children and the elderly and health and education.

Ministry of Housing & Urban Affairs:

MoHUA is the key ministry of the union government of India driving this initiative in Mission Mode thru the National Smart City Mission.

Smart City Mission: Smart Cities Mission of the Government is a bold, new initiative. Objective of the Smart Cities Mission is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions.

The focus is on sustainable and inclusive development, and the idea initially is to look at compact areas, create a replicable model, which will act like a lighthouse to other aspiring cities. The Smart Cities Mission is meant to set examples that can be replicated both within and outside the Smart City, catalyzing the creation of similar Smart Cities in various regions and parts of the country.

The strategic components of the Smart Cities Mission are city improvement (retrofitting), city renewal (redevelopment) and city extension (Greenfield development) plus a Pan-city initiative in which Smart Solutions are applied covering larger parts of the city.

Area-based development will transform existing areas (retrofit and redevelop), including slums, into better planned human settlements, thereby, improving liveability of the whole cities. Development of well-planned and fully serviced new areas (greenfield) will be encouraged around cities in order to accommodate the rapidly expanding population in urban areas. Application of Smart Solutions will enable cities to use technology to improve infrastructure and services.

Comprehensive development in this way will improve quality of life, create employment and enhance incomes for all, especially the poor and the disadvantaged, leading to inclusive cities.

The core infrastructure elements in a Smart City would include:

- ⇨ Adequate water supply,

- ⇨ Assured electricity supply,
- ⇨ Sanitation, including solid waste management,
- ⇨ Efficient urban mobility and public transport,
- ⇨ Affordable housing, especially for the poor,
- ⇨ Robust IT connectivity and digitalization,
- ⇨ Good governance, especially e-Governance and citizen participation,
- ⇨ Sustainable environment,
- ⇨ Safety and security of citizens, particularly women, children and the elderly, and
- ⇨ Health and education.

The Mission will cover 100 cities and its duration will be five years (FY2015-16 to FY2019- 20). The Mission may be continued thereafter in the light of an evaluation to be done by the Ministry of Housing & Urban Affairs (MoHUA) and incorporating the learnings into the Mission.

The Ministry of Housing & Urban Affairs supported the Mission through the design of the India Smart Cities Challenge. The Challenge, in which Indian cities compete for central government funding, marks the first time the Government of India, has used a competitive framework to advance a major urban development mission and allocate funding.

The Government did not prescribe any particular model to be adopted by the Smart Cities. The approach was not 'one-size-fits-all'; each city had to formulate its own concept, vision, mission and plan (proposal) for a Smart City that is appropriate to its local context, resources and levels of ambition. Accordingly, they had to choose their model of Smart City and answer the question: What kind of Smart City do they want? For this, cities were required to prepare their Smart City Proposal (SCP) containing the vision, plan for mobilization of resources and intended outcomes in terms of infrastructure up-gradation and smart applications.

Cities were required to prepare SCPs using the principles of strategic planning process and the proposal will contain area-based development plans and Pan-city initiatives. The SCP is collaborative because the objectives and funds of all government departments, parastatals, private agencies and the citizens are dovetailed during the process of preparing the SCP.

Ministry of Electronics & Information Technology

Ministry of Electronics & Information Technology is responsible for formulation of National Policies, Regulations and Guidelines in the field of Electronics & I T in India. Currently it is driving some of the most challenging Initiatives to bring the Nation at par with Developed Nations. Some of the crucial initiatives being:

- ⇨ E-Governance
- ⇨ Digital India
- ⇨ Digital Locker
- ⇨ Cyber Security
- ⇨ Cloud Governance
- ⇨ Standards, Testing, Quality & Certification in Electronics and IT products, systems & Solutions.

MeitY is working very closely with MoHUA & Industry to support the Smart City initiatives by providing guidance on relevant standards, policies and Innovation & R&D support to realize the Smart City vision and empower the citizens.

Ministry of Telecommunication

Ministry of Telecom is responsible for formulation of National Policies, Regulations and Guidelines in the field of Telecommunication in India. The technical wing of the MoT is TEC – Telecom Engineering Centre. TEC is a technical body representing the interest of Department of Telecom, Government of India. TEC roles & responsibilities are:

- ⇨ To Prepare specification of common standards with regard to Telecom network equipment, services and interoperability.
- ⇨ To release Specifications as Generic Requirements (GRs), Interface Requirements (IRs) and Service Requirements (SR).
- ⇨ To Issue Interface Approvals, Certificate of Approvals, Service Approvals & Type Approvals.
- ⇨ To Formulate Standards and Fundamental Technical Plans.
- ⇨ To Establishment of state-of-art telecom laboratories.
- ⇨ Interact with multilateral agencies like APT, ETSI and ITU etc. for standardisation.
- ⇨ Develop expertise to imbibe the latest technologies and results of R&D.
- ⇨ Provide technical support to DoT and technical advice to TRAI & TDSAT.
- ⇨ Coordinate with C-DOT on the technological developments in the Telecom Sector for policy planning by DoT.

TEC, in its M2M Working Groups has been working to review the Telecom Aspects of Smart Cities and has been releasing reports addressing various vertical & horizontal aspects of telecommunication relevant to Smart City, Smart Infrastructure, M2M/IoT paradigms.

TSDSI

TSDSI (Telecommunications Standards Development Society, India) is an SDO that aims at developing and promoting India-specific requirements, standardizing solutions for meeting these requirements and contributing these to international standards, contributing to global standardization in the field of telecommunications, maintaining the technical standards and other deliverables of the organization, safe-guarding the related IPR, helping create manufacturing expertise in the country, providing leadership to the developing countries (such as in South Asia, South East Asia, Africa, Middle East, etc.) in terms of their telecommunications-related standardization needs. TSDSI represents Indian perspective in Standardization at Global Telecom SDOs viz.: ITU, 3gpp, oneM2M…

TSDSI in its Working Group on M2M had done an extensive work to collect use cases for the Smart Infrastructure Domain. Currently it is trying to align its roadmap with Indian requirement and collaborating with all the stakeholders to harmonize the Standardization work in Telecom domain.

Project SESEI:

EU Project SESEI [Seconded European Standardization Expert in India] is a 5-partner's project based in New Delhi, India, with the objective to increase visibility of European standardization and promote EU/EFTA-India cooperation on standards and related issues. It is a Standardization focused project, with a priority emphasis on the sectors of ICT, Automotive, Electronic Equipment including Consumer Electronics and Smart Cities etc. Project also keep track of Manufacturing, R&D and Innovation, EU-INDIA FTA etc. Project work closely with Indian Standardisation community covering Bureau of Indian Standards (BIS), Telecom

Standards Development Society, India (TSDSI), Telecommunication Engineering Centre (TEC) under Department of Telecom and other Industry stakeholders and associations. The Project is managed by the European Telecommunications Standards Institute (ETSI), a European Union recognized Standards Organization, and is further supported by the other two recognized EU Standards Organizations CEN and CENELEC. The other two partners to this Project are the European Commission and the European Free Trade Association.

Priority areas of focus identified for the SESEI project are as follows:

- ⇨ Information and communication technology: M2M/IoT, Security, 5G, NFV/SDN…
- ⇨ Electrical and electronic household products, Smart Grid, Smart Meter…
- ⇨ Automotive: Connected Cars, ITS…
- ⇨ Smart Cities
- ⇨ Environmental

India EU ICT Standardization Collaboration:

The overall objective of the EU funded project **"**India-EU Cooperation on ICT-Related Standardisation, Policy and Legislation**"** (2015 **–** 2019) is to promote closer alignment between India and Europe with regard to the production and use of ICT standards and to harmonize the exchange of statistical data, thereby facilitating trade, increasing interoperability and the ease of doing business for companies on both sides, and adding additional weight to European and Indian ICT standardisation efforts at the global level.

The project strengthens cooperation between the European and Indian telecommunications standards bodies "European Telecommunications Standards Institute" (ETSI) and "Telecom Standards Development Society of India" (TSDSI), including their members and partners from public administration, academia/research, sector associations, industry, and related start-ups. Cooperation means exchanges of viewpoints and approaches towards standards, and developing standards together as equal partners for the global economy. Both sides can benefit from eliminating trade barriers and through gathering expertise to be utilized for research and development, production and global sales of products complying with globally accepted standards. The trustful and respectful cooperation is implemented through regular joint meetings, workshops, conferences, webinars, the international exchange of experts, trainings, travel support for attending relevant meetings, developers days, hackathons, position papers and analyses/studies, and other joint activities for selected pilot topics 1) 5G Networks, 2) Machine to Machine (M2M) communications / Internet of Things (IoT) with special focus on Intelligent Transport Systems (ITS) applicable to smart cities, 3) Software-Defined Networking (SDN) / Network Functions Virtualization (NFV); and Security as a horizontal topic.

NASSCOM

NASSCOM, a not-for-profit industry association, is the apex body for the 154 billion dollar IT BPM industry in India, an industry that had made a phenomenal contribution to India's GDP, exports, employment, infrastructure and global visibility.

NASSCOM has proposed a smart city framework for India, which is driven by the unique challenges faced by the Indian cities. It covers the physical, social, environmental and institutional (governance) infrastructure requirements for a smart city driven by stakeholder

collaboration and one which extensively leverages the advances made in the domain of Information and Communication Technologies.

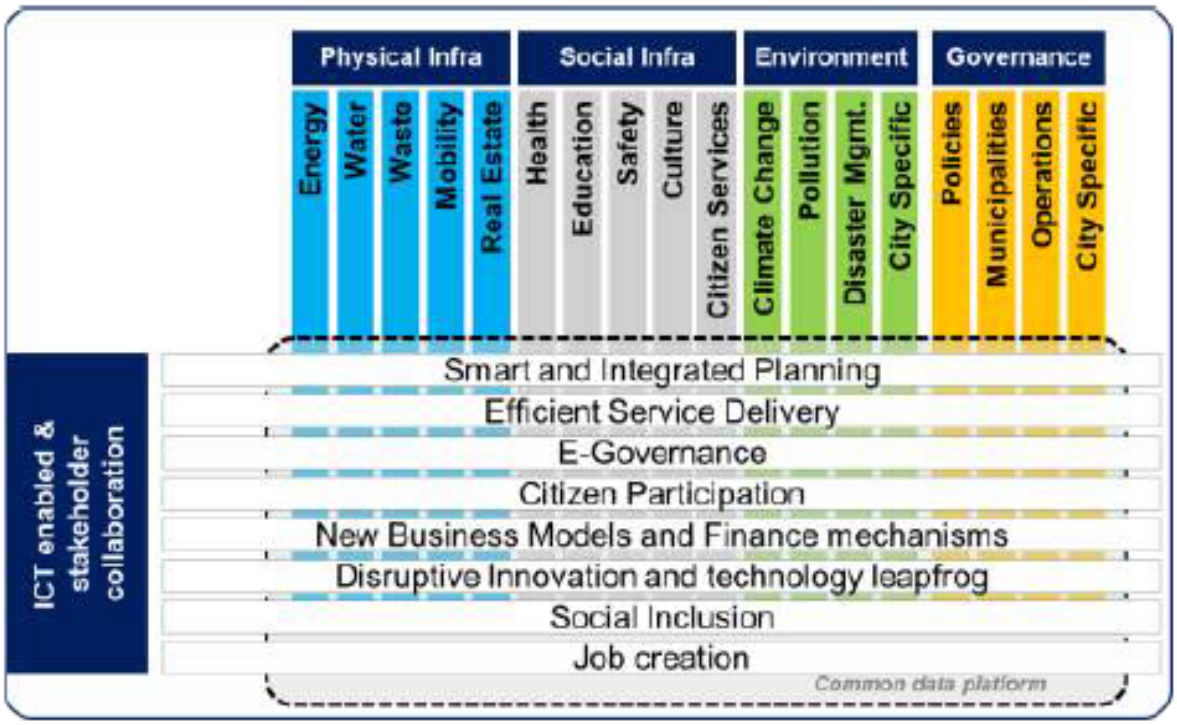
The framework covers physical and social infrastructure, environment and governance systems required to design a smart city. Each of the parameters has been further elaborated to layout the components.

Physical infrastructure: Physical infrastructure illustrates requirements within various layers of energy, water, waste, mobility and real estate necessary for a robust smart city infrastructure. The objective here is to provide cost-efficient and intelligent physical infrastructure such as electricity supply, transport and traffic infrastructure, water supply system, sewerage system, sanitation facilities, drainage system and building energy, security systems, etc.

Social infrastructure: Social infrastructure relates to provisions of healthcare, education, safety, cultural requirements and establishments for citizen services required by the city. Smart social infrastructure aims to ensure intelligent and better connected infrastructure for various social needs and services for citizens

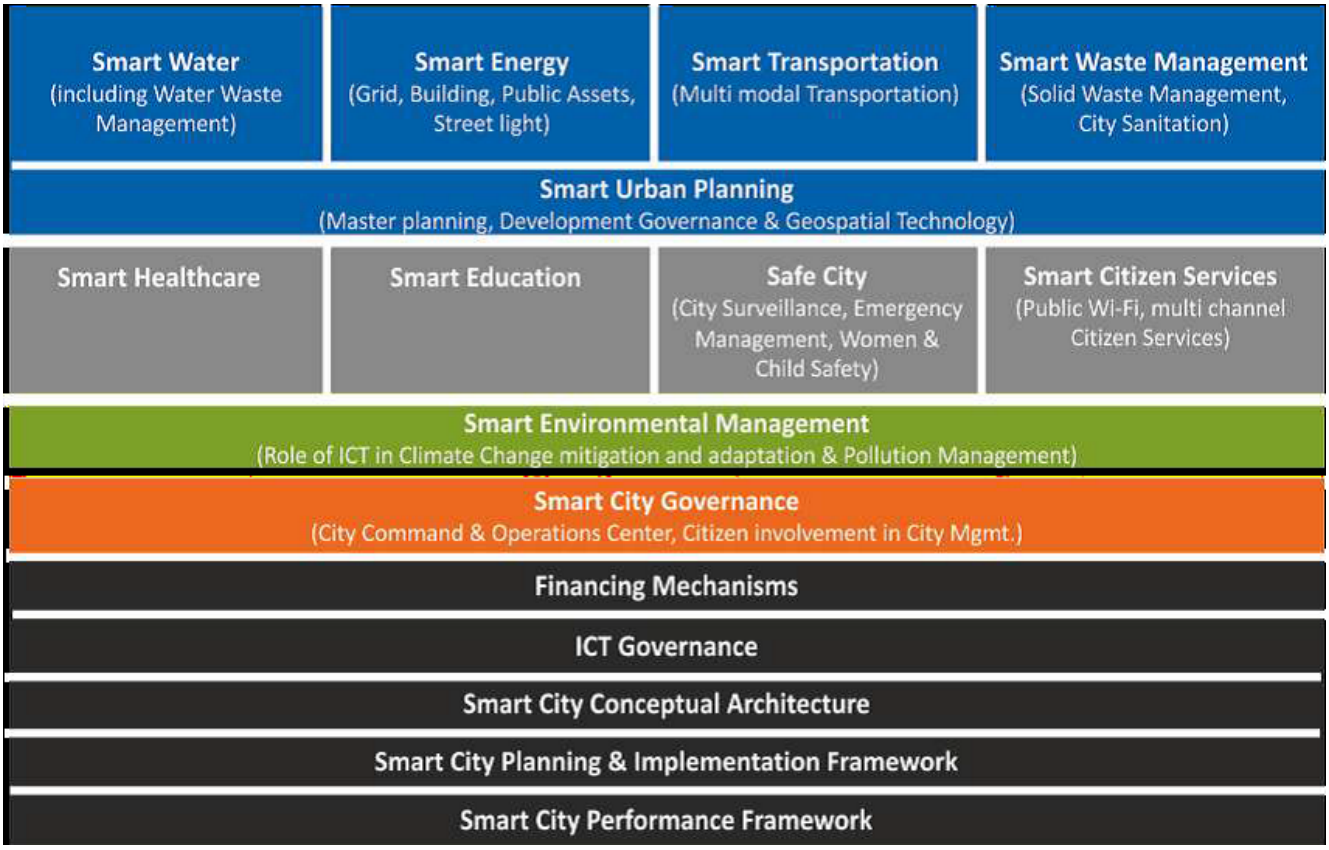
Environment: Smart cities need to be sustainable and environment-friendly. There need to be systems and processes in place to address climate change, pollution, disaster management and any city specific issues.

Governance: Smart city should comprise governance mechanisms to ensure proper functioning of all other systems and processes. This begins with having requisite policies and regulatory mechanisms, an urban local body to execute processes along with an execution mechanism



Overall smart city framework for India

ICT and Geospatial Technologies (GT) plays a crucial role in improving quality of life of citizens, improving business infrastructure and reducing impact on environment. ICT-GT technologies have the ability to improve performance, capacity and efficiency of physical, social, environmental and institutional (governance) infrastructure. Considering the role that ICT and geospatial technologies can play in improving city performance, Integrated ICT and Geospatial Technologies Framework for 100 Smart Cities Mission is designed in alignment with the overall smart city framework for India.



Smart city ICT and geospatial technologies framework

Synergies with Key National Programs- The 100 smart cities program can create significant synergies with other infrastructure related Government of India projects such as Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Heritage City Development & Augmentation Yojana (HRIDAY) and Swachh Bharat Mission (SBM).

BIS

The Bureau of Indian Standards (BIS), the National Standards Body of India is a statutory organization under the Bureau of Indian Standards Act, 1986. Objectives of BIS being

- ⇨ Harmonious development of standardization, marking and quality certification
- ⇨ To provide new thrust to standardization and quality control
- ⇨ To evolve a national strategy for according recognition to standards and integrating them with growth and development of production and exports

BIS has Two Committees working on Standardization in the Smart City domain:

- ⇨ **CED 59** – Sectional Committee under Civil Engineering Division Council. CED59 is the Nation Mirror Committee of ISO/TC 268 with scope - Standardization in the field of Smart Cities - Terminology, Components, Planning, Design, Integration, Implementation, Operation, Maintenance and Assessment.

- ⇨ **LITDC/P2** – Panel on "Smart Infrastructure" under Electronics & IT Division Council. This Panel is the National Mirror Committee of:
  - IEC Systems Committee on Smart Cities
  - ISO/IEC JTC1/WG11 on Smart Cities
  - IEC Systems Committee on Smart Energy
  - IEC Systems Committee on Active Assisted Living

Besides the above, this Panel is also responsible for mapping Global Standardization activities in the fields of Smart Manufacturing, Smart Homes & Buildings and all aspects of Communication & Information Technologies relevant to Smart Infrastructure domain. The scope of this Panel is enumerated in the Forward of this report.

STANDARDIZATION IMPERATIVES:

"Standards & even SDOs are not at the forefront of Cities', Utilities' or Users' minds"

There are misconceptions on what standards are for, and, the case for use of standards has not been made. Liberalization and Markets have a lot of great virtues, but they cannot create their own conditions of existences: **they must be designed!**

CACOPHONY or SYMPHONY

The Enraged Musician, William Hogarth, 1741

Standards are the chromosomes of Smart Infrastructure

Study - PART 1 Section 2

Understanding Smart City

Market and Stakeholders

&

Review of Smart Cities Use cases

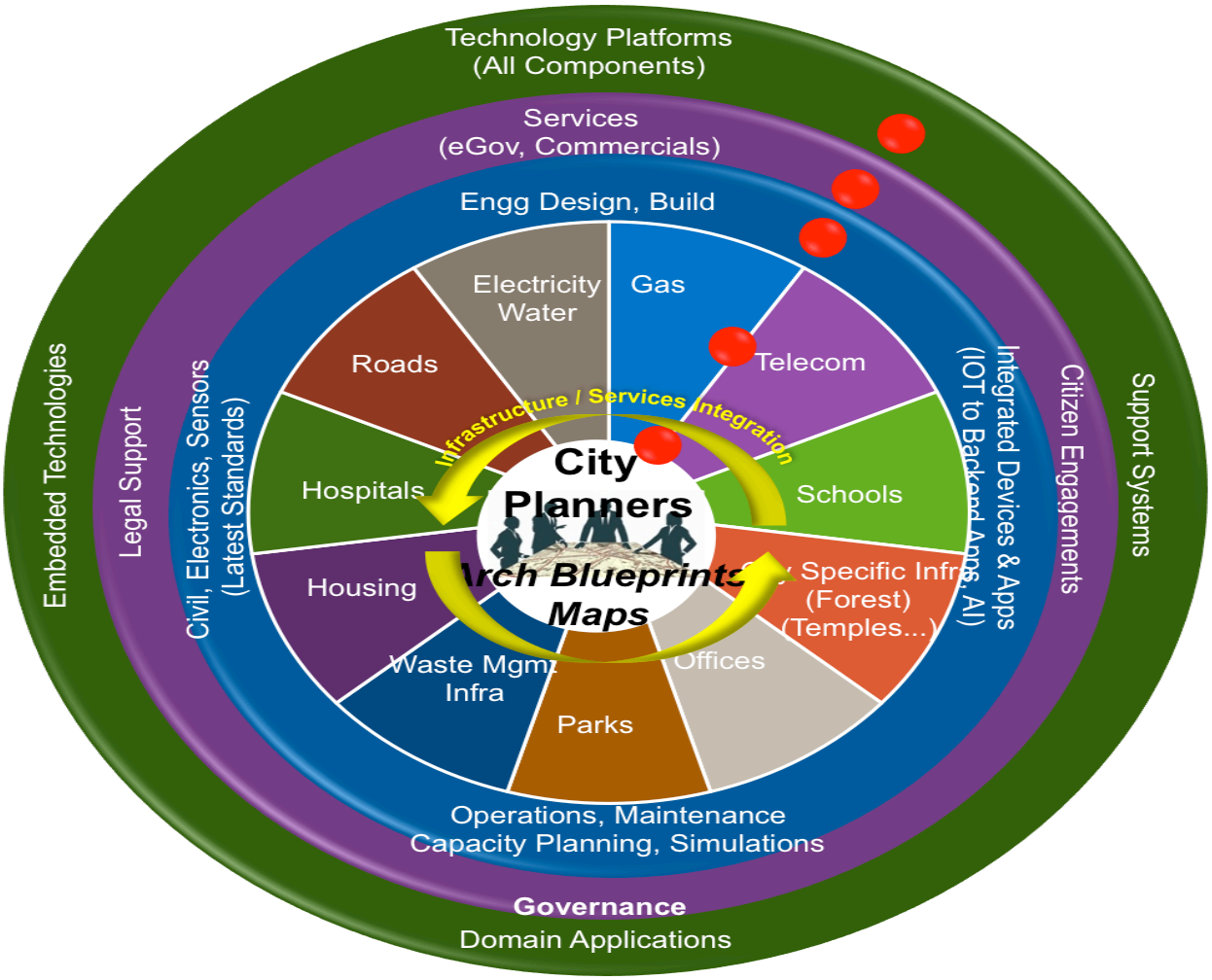
from

Standardization Perspective

Market, Stakeholders & Use cases Review:

Sustainable development of any Nation depends on the development of sustainable cities, which can only be achieved through the wide-reaching roll out of integrated, scalable, Smart/sustainable-city/community solutions.

Sustainable, smart cities and communities will contribute to sustainable development and resilience, through soundly based decision - making, and the adoption of both a long and a short-term perspective.



The City Imperatives

As proposed by ISO TC 268 "Sustainable development in Communities"; the 6 purposes of sustainability and smartness for cities and communities is to strengthen:

- ⇨ Social cohesion, population consensus, inclusivity (participation of all)
- ⇨ Well-being, creativity and innovation
- ⇨ Preservation and improvement of environment
- ⇨ Responsible Resource use

- ⇨ Attractiveness, supporting Indian businesses and providing a level playing field
- ⇨ Resilience

The 12 major relevant issues for Smart Sustainable Cities & Communities identified by ISO TC 268:

- ⇨ Governance
- ⇨ Education
- ⇨ Innovation
- ⇨ Health and care
- ⇨ Culture
- ⇨ Living together
- ⇨ Economy
- ⇨ Living and working environment
- ⇨ Safety and security
- ⇨ Smart community infrastructures
- ⇨ Biodiversity
- ⇨ Mobility

The importance of collaboration within the city:

Stakeholders and interested parties

Citizen

The key focus of Smart city is the citizen and the benefit such a concept brings to the citizen not only as a passive recipient but as an equal and active participant who participates and contributes to improving his own and his fellow citizens' lot.

City as a whole

A very important stakeholder of the Smart City is the City taken as a whole. It is to be understood that a city can be an unknown one among numerous ones or can be one of the important city which is variously desirable to people to inhabit and visit it and it carries a elements like heritage, legacy, present day ambience and aura and which gives it a value (something akin to a Brand Value) intrinsic to it.

The collaboration between a set of key stakeholders and interested parties is a key component of the achievement of a sustainable and smart city. These may belong to one or several specific categories:

- ⇨ Public authorities: national, regional, local government and municipalities ... ,
- ⇨ Developers and Investors: Public or private, promoters trades ...
- ⇨ Industry and operators of public or private services
- ⇨ Public interests groups, and associations
- ⇨ Permanent or temporary residents, inhabitants, businesses, consumers
- ⇨ Banks, insurers
- ⇨ Consumers/citizens
- ⇨ Prosumers i.e. consumers who also produce

Within this, the key perspective to focus on is that of the **"citizen"**, this term being taken, in the context, broadly to mean individual citizen and their families.

The Citizen Perspective

In the smart/sustainable-city/community context, the term "consumer" is to be taken broadly, to mean individual citizens and their families.

The smart community offers considerable opportunity not only for citizens to have an improved living environment in which they can benefit from effective services, but also for

them to have an additional say in matters affecting their daily lives. At the same time, equal treatment for all citizens needs to be ensured, and account needs to be taken of "big data" risks to their personal information.

Against this background, citizens need:

- ⇨ Transparent information about the public and commercial services being provided in a smart/sustainable- city/community, what is their cost, what are their rights and the redress procedures when they go wrong, etc.;
- ⇨ Mechanisms to ensure their individual voice is heard;
- ⇨ Assurances that the security of their personal information is properly protected and that this data will not be misused for commercial purposes;
- ⇨ Support and education for those unable to take immediate and full advantage of smart community living;
- ⇨ A physical environment that ensures accessibility for older people and those with disabilities.

The India Perspective

The Biggest Challenge: Livelihoods

- ⇨ India will have about 400 million additional persons in the labor force by the year 2050.
- ⇨ Agriculture and related activities that provide subsistence to about 220 million of the current workforce of 500 million cannot absorb this additional labor without further reducing levels of earnings.
- ⇨ **There has to be a massive transfer of people from primary to secondary and tertiary sectors, and from rural to urban areas.**
- ⇨ Industries and businesses are moving away from megacities into lower order cities or rural locations, while the informal sector is moving into the megacities.
- ⇨ It is the **non-polluting tertiary activities** and growth of **select informal sector** that are driving the limited urbanization in million plus cities
- ⇨ **Informal livelihoods must be integrated into urban plans and zoning regulations**: unorganized workforce gains access to markets and basic amenities

CHALLENGES: TACKLING COMPLEXITY - 1

DEMOGRAPHY

- ⇨ Annual growth rate of population: ~2.35 % **(2.76)**
- ⇨ Average density: 8502 persons per square km.
- ⇨ Average area of 20 smart cities: 135.6 sq.km. (Average area of Urban India: 12.92 sq.km.)
- ⇨ 85.68 of the population is literate **(84.11)**
- ⇨ 57.67 of the households live in self-owned houses **(69.1)**
- ⇨ 28.3 of households live in congested houses **(32.9)**
- ⇨ 18.1 percent resides in slum areas **(17.4)**
- ⇨ Every 13th person is poor (~7%) **(13.7)**
- ⇨ Youth: 17.9 % of total population **(19.6)**

ECONOMY

- ⇨ Working age group: 60.25 % population **(65.2)**
- ⇨ Workforce participation: 35.8 % **(35.5)**

- ⇨ Per Capita Income: Rs. 43,797 per month (~584 Euro) **(Rs. 35,947)**
- ⇨ Employment: Self-employed- 41.8% **(42.0%),** Regular wage/salaried employees- 42.1% **(44%)**, Casual Labor- 16 % **(14%)**
- ⇨ Sectors: Primary Sector 6.5% **(8%)**, Secondary Sector 35.2 % **(34%)**, Tertiary Sector 58.2% **(58%)**

CHALLENGES: TACKLING COMPLEXITY - 2

INFRASTRUCTURE

- ⇨ 75.7 % households have access to tap water **(62.01)**
- ⇨ 95 % households have access to electricity **(92.67)**
- ⇨ 80.7 % households have toilet facilities within premises **(72.5)**
- ⇨ 86.6 % households are connected to drainage **(81.7)**
- ⇨ 9.5 % households have access to computer with internet **(8.2)**
- ⇨ 65.35 % households have mobile phones **(64.3)**
- ⇨ Mobility: Bicycle – 43.7% **(41.9)**, two-wheelers – 41.7% **(35.2%)**, four- wheelers – 12.2% **(9.7%)**

GOVERNANCE

- ⇨ Elections held regularly but tenure of mayor is not fixed (1.5 - 5 yrs.)
- ⇨ 50 % of the statutory towns do not have a development (master) plan
- ⇨ On average, 25 % of the municipal budget is allocated for the poor
- ⇨ 'Own Revenues' comprise ~ 50 % of the city's earnings; grants and aid constitute the remaining half
- ⇨ Property Tax comprises ~ 70 % of the 'Own Revenues'; remaining comprises user charges, license fees and other taxes

Other CHALLENGES:

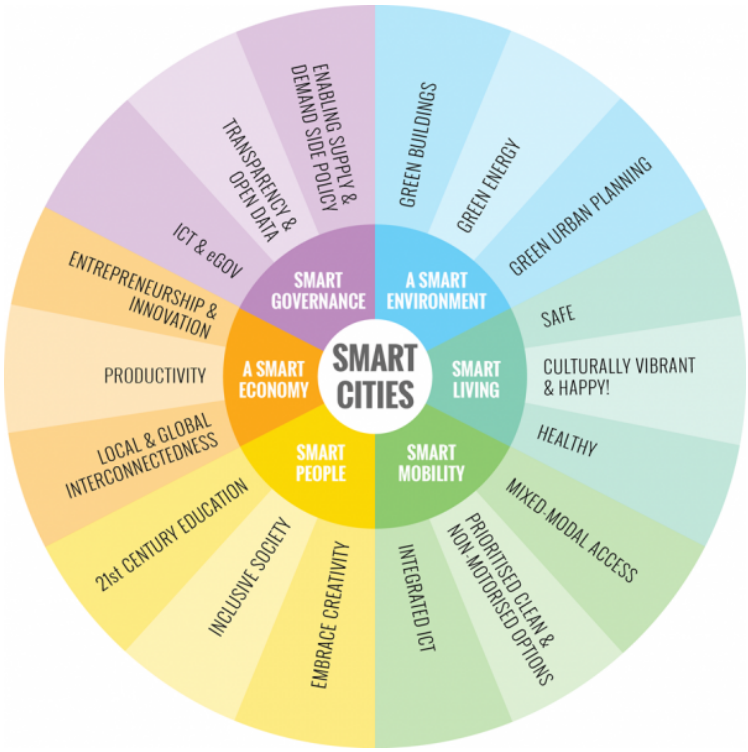
- ⇨ Holistic Thinking
- ⇨ Selecting appropriate role models
- ⇨ Promoting Innovation
- ⇨ **Energy**
  - o Integrate Energy and Waste Management
  - o Promote Low Carbon Mobility
- ⇨ **Building Construction**
  - o Integrate Building Systems and City Networks/Systems
  - o Advance Materials Sciences
  - o **T**otal **Q**uality Management
- ⇨ **Urban Management**
  - o Use (hygienic) Big & Open data for simulation and modeling
  - o Revamp curricula in architecture, planning, engineering
  - o Study Urban Networks & Systems
  - o Converge networks and technologies through IOT, M2M and standardization
  - o Command & Control Centers

India: Areas of concern

Housing, Slums, Overcrowding, Public Safety, Garbage, Pollution, Infrastructure, Transportation, Disaster Management, Education, Healthcare, Governance, Accountability, Transparency…

Leveraging India's uniqueness:

Socio Economic Disparity, Religion, Co-existence, Interdependence, Non-demanding Citizens, Collective Voice, Tolerance, Coping Mechanism, Youth, Growth, Entrepreneurial Spirit… Can Technology help leapfrog?



India Opportunities:

- ⇨ **UID Integration** with Planning and Execution
- ⇨ **GIS enables integration** of planning, finance and management
- ⇨ Fast growth in availability of **Big Data**
- ⇨ **1.2 billion** wireless subscribers (300 million Broadband)
- ⇨ **Urban Tele-density** – 167 connections per 100 inhabitants
- ⇨ **Youthful society** can fully utilize 'Smart' paradigm
- ⇨ Innovation & Enterprise **Potential (**Frugal Technologies)
- ⇨ **IT industry** among fastest growing in the country
- ⇨ **High Acceptance of E-Governance**: In 2012, 98,000 Common Service Centers providing E-governance services; over 600 out of 1100 citizen and business services available electronically

The SMART (ER) Way ahead

- ⇨ Promote integrated planning & bundling: **Convergence**
- ⇨ Promote e-Governance: **TRANSPARENCY**
- ⇨ Promote informal sector and SMEs: **Inclusion & diversity**
- ⇨ Decentralize planning & management: **DEVOLUTION**
- ⇨ Measure resources and consumption: **decoupling**
- ⇨ Enhance public participation: **Trust**
- ⇨ Promote 'Triple Helix': **PARTNERSHIP**
- ⇨ Make in India: **ZERO 'EFFECT' ZERO DEFECT**
- ⇨ Support Entrepreneurship and Innovation: **THE NEXT GENERATION**

Smart Cities Mission

India began its Smart Cities journey in June 2015 with launch of 100 Smart Cities Plan with the following initial Imperatives:

- ⇨ To provide a secure & sustainable Basic Infrastructure and environment
- ⇨ To use Smart Solutions to improve the Infrastructure, Services & quality of life of its citizens
- ⇨ To Rely on Area Based Development

To set examples that could be replicated both within and outside the Smart City, and catalyze the creation of similar Smart Cities.

Accordingly, the purpose of the Smart Cities Mission is to drive economic growth and improve the quality of life of people by enabling local area development and harnessing technology, especially technology that leads to Smart outcomes. Area-based development will transform existing areas (retrofit and redevelop), including slums, into better-planned ones, thereby improving livability of the whole City. New areas (greenfield) will be developed around cities in order to accommodate the expanding population in urban areas. Application of Smart Solutions will enable cities to use technology, information and data to improve infrastructure and services. Comprehensive development in this way will improve quality of life, create employment and enhance incomes for all, especially the poor and the disadvantaged, leading to inclusive Cities.

Smart City Features

Some typical features for comprehensive development in Smart Cities as envisaged by the Smart Cities Mission are:

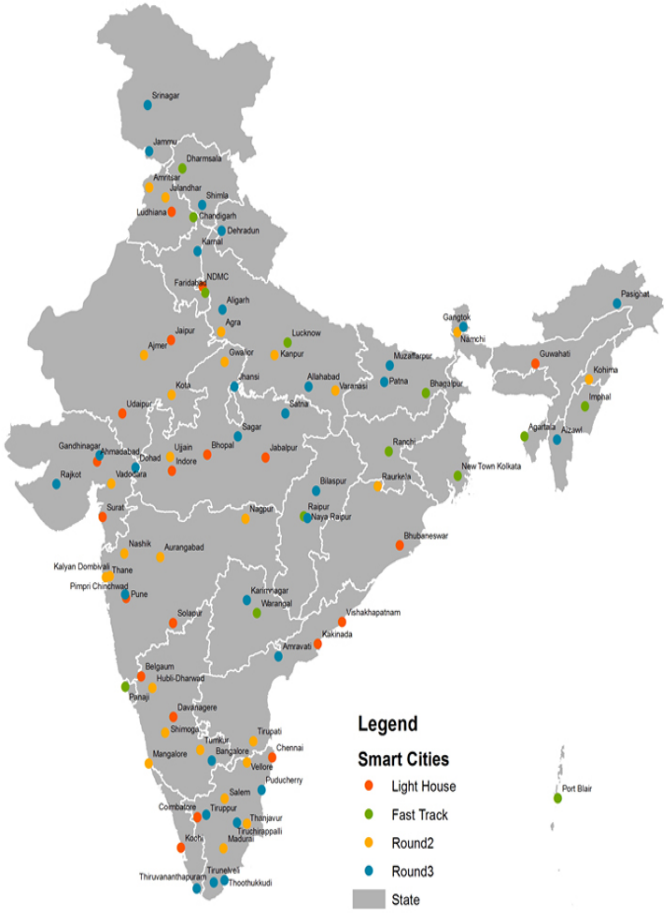
- ⇨ Promoting mixed land use in area based developments–planning for 'unplanned areas' containing a range of compatible activities and land uses close to one another in order to make land use more efficient. The States will enable some flexibility in land use and building bye-laws to adapt to change;
- ⇨ Housing and inclusiveness - expand housing opportunities for all;
- ⇨ Creating walk able localities – reduce congestion, air pollution and resource depletion, boost local economy, promote interactions and ensure security. The road network is created or refurbished not only for vehicles and public transport, but also for pedestrians and cyclists, and necessary administrative services are offered within walking or cycling distance;
- ⇨ Preserving and developing open spaces - parks, playgrounds, and recreational spaces in order to enhance the quality of life of citizens, reduce the urban heat effects in Areas and generally promote eco-balance;
- ⇨ Promoting a variety of transport options - Transit Oriented Development (TOD), public transport and last mile Para-transport connectivity;
- ⇨ Making governance citizen-friendly and cost effective - increasingly rely on online services to bring about accountability and transparency, especially using mobiles to reduce cost of services and providing services without having to go to municipal offices. Forming e-groups to listen to people and obtain feedback and use online monitoring of programs and activities with the aid of cyber tour of worksites;

- ⇨ Giving an identity to the city - based on its main economic activity, such as local cuisine, health, education, arts and craft, culture, sports goods, furniture, hosiery, textile, dairy, etc.;
- ⇨ Applying Smart Solutions to infrastructure and services in area-based development in order to make them better. For example, making Areas less vulnerable to disasters, using fewer resources, and providing cheaper services.

Key elements of Smart City Proposals

- ⇨ Area Based Development
  - o Only one 'Area' should be selected.
  - o Area delineated should be contiguous and not at separate locations in the city.
- ⇨ Either of three types of development:
  - o Retrofitting (approx. 500 acres),
  - o Redevelopment (approx. 50 acres) or
  - o Greenfield development (approx. 250 acres)
- ⇨ Pan City Solution
  - o Cities may propose one or two such Smart Solution

However, the Pan-city Smart Solution should be IT enabled and improve governance and/or pubic services



Smart city Mission-Updates

Indian Smart Cities – Key Focus Areas

- ⇨ Integrated Command Centre & Dash Board
- ⇨ Citizen Services
- ⇨ Unified & Secure ICT Back-bone
- ⇨ Energy, Water & Solid Waste Management
- ⇨ Integrated Transport System
- ⇨ Cyber & Network Security
- ⇨ 3 rounds of bidding concluded
- ⇨ 90 Smart Cities identified through extensive selection process
- ⇨ Total Urban Population Impacted – 95,955,046
- ⇨ Total Cost of Projects – 189,256 Crores
- ⇨ Total Area Based Development Cost = 152,600 Crores
- ⇨ Total Pan City Solution Cost – 36,656 Crores
- ⇨ Total investment till date up to Rs.1, 91,155 cr.
- ⇨ Smart City Mission Report Card by The Urban Development Ministry
- ⇨ City Livability Index launched by Ministry of Urban Development

Review of the 60 Smart City Projects' Proposals provides the following Insights:

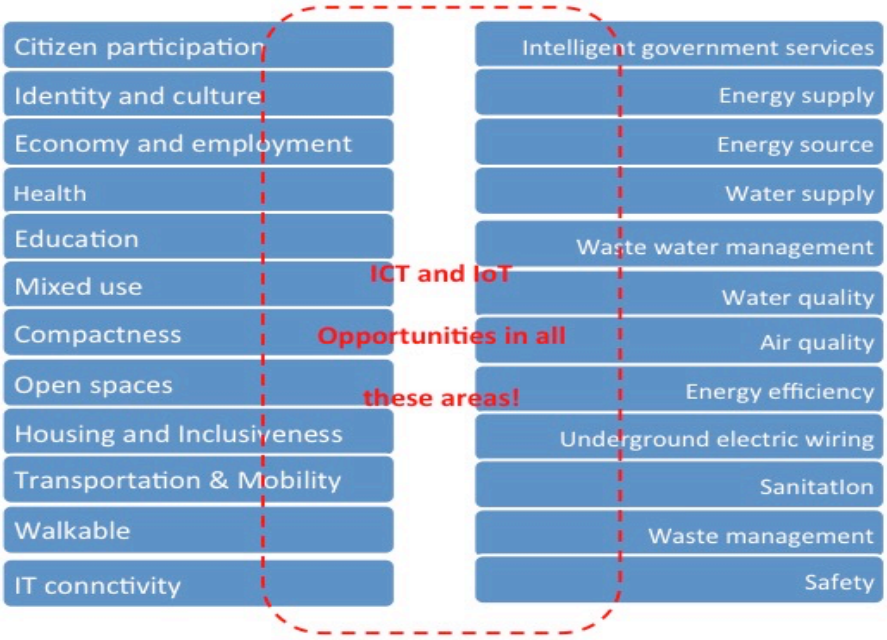
Amongst the unique Use Cases identified in the 60 proposals

- ⇨ 43 Use Cases (47%) are about the ICT Needs and
- ⇨ 48 Use Cases (53%) are about the Non-ICT needs of the cities.

Further granular analysis of ICT Use Cases showed the domain-wise breakup as –

- ⇨ Water – 81 (17%);
- ⇨ Energy – 93 (20%);
- ⇨ Waste Management – 57 (12%);
- ⇨ Surveillance, C& C (Command & Control),
- ⇨ Connectivity – 45 (10%);
- ⇨ Transportation – 105 (22%);
- ⇨ Other – 88 (19%).

Features of a Smart City: 24 Features identified by MoUD, G o I.



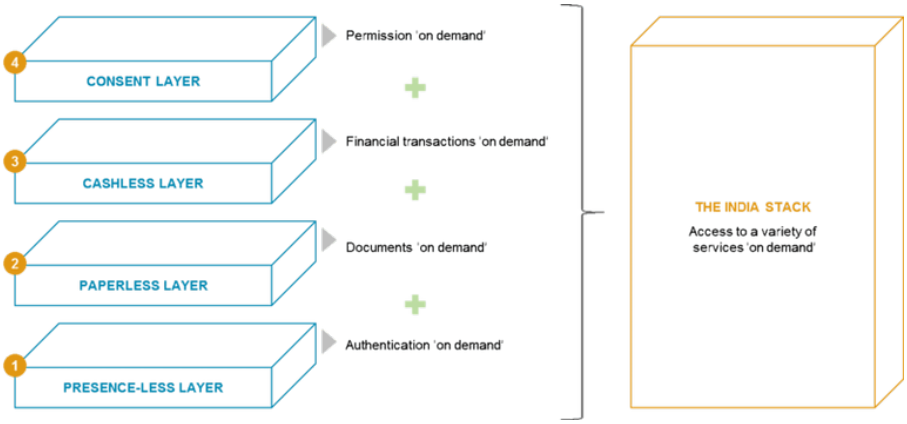
The India Stack:

For a successful implementation of integrated architecture, it is essential to chart out various government departments and their evolving technology needs for next X years and find common ground. Technology assisted governance models and platform based implementation practices based on the India Stack (JAM) should be a key foundation. The measure requires an in-depth financial estimation to chart out the organizational cost benefits of using common platform.

India Stack refers to the ambitious and controversial project of creating a unified software platform to bring India's population into the digital age. "India Stack is a set of APIs that allows governments, businesses, startups and developers to utilize an unique digital Infrastructure to solve India's hard problems towards presence-less, paperless, and cashless service delivery". The four "distinct technology layers":

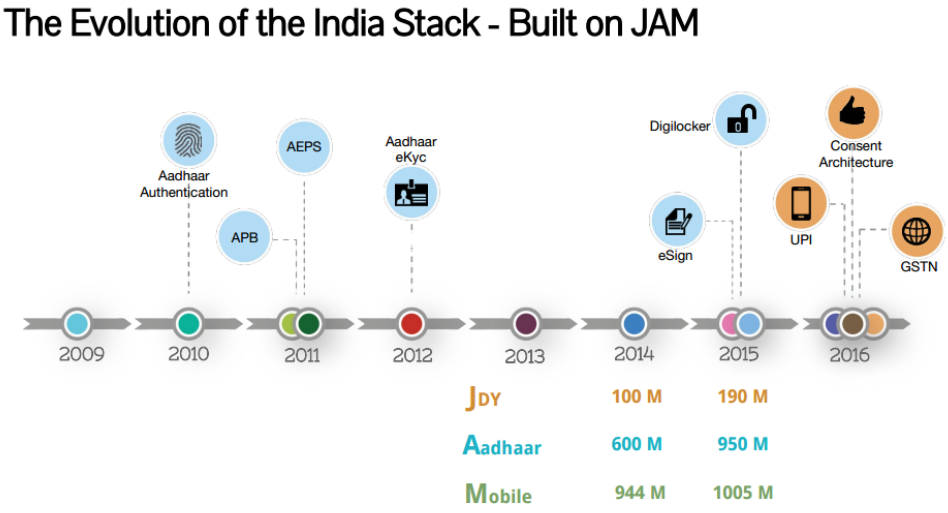
- ⇨ The Presenceless Layer is Where a universal biometric digital identity allows people to participate in any service from anywhere in the country.
- ⇨ The Paperless Layer - Where digital records move with an individual's digital identity, eliminating the need for massive amount of paper collection and storage.
- ⇨ The Cashless Layer - Where a single interface to all the country's bank accounts and wallets to democratize payments. And
- ⇨ The Consent Layer - Which allows data to move freely and securely to democratize the market for data.

India Stack is the largest open API in the world. Since its deployment, India has been organizing hackathons to develop applications for the APIs.



India Stack is being implemented in stages, starting with the introduction in 2009 of the Aadhaar "Universal ID" numbers. These are linked to biometrics (fingerprints) and as time goes by, authentication by Aadhaar is required for access to more and more services and subsidies. This raises issues of privacy and surveillance, especially as much of the users' interface is via their mobile phones.

The next stages were the introduction of eKYC (electronic Know Your Customer), which enables paperless and rapid verification of address, identity etc., followed by e-Sign, whereby users attach a legally valid electronic signature to a document, and UPI (Unified Payments Interface) enabling cashless payments, and most recently, DigitalLocker, a platform for issuance and verification of documents & certificates.



Evolution of the India Stack Source: Ericsson Mobility Report

What raised the profile of Aadhaar and India Stack worldwide was the recent "demonetization" whereby 500 and 1000 Rupee notes were phased out, officially to eliminate forgeries and money-laundering, but with the secondary objective of hastening the transition to a cashless economy. Observers have argued that India Stack could fast-track the move to digital payment systems across the developed world and mark the end of cash.

Current Challenges

The current state of Smart Cities Challenge Proposals has several gaps that need to be addressed:

- Closed Solutions: Available solutions are extremely closed with an ecosystem that is highly locked-in by vendors i.e., a single vendor owns the vertical application, platform, communication, services, and data. While convergence of technology, unified standard, interoperability, etc., are necessary to ensure customer-centric systems, open markets are essential for competitive, affordable and sustainable solutions. The existing ecosystem allows minimal or no flexibility.
- Force-Fitting Solutions developed for Mature Markets: There is a natural tendency to force-fit existing solutions developed for other cities such as Madrid, Barcelona, etc., to the proposed smart cities in India. This may not be the right approach given the requirements, constraints and challenges in India. India specific needs should be factored-in upfront in the architecture of these solutions.
- Inappropriate Last Mile Solutions: Existing last mile technology for wireless sensor networks are undergoing rapid change to meet radical lower levels of capital and operation cost and much higher level of reliability for mass usage in smart cities. We may need to contract wisely to encourage experimentation and migration to successful new approaches rather than get locked into a high cost solution such as the Dabhol Power Station.
- Deployment Diversity: Different Cities are expected to contract separately but we need a method to benefit from some commonality and State-to-State arrangements.
- Non-Standard Disharmony: There is no common framework and architecture defined for the various physical infrastructures to be deployed in the proposed smart cities to work in an integrated, harmonized and optimized manner.
- Dichotomy: There is a dichotomy between, on the one hand, the need for investment in R&D for new products, systems and solutions based on an integrated and secure System Architecture when there is little awareness about the problem among stakeholders, and on the other hand, the creation of a unified System Architecture and Framework where there is no demand due to ignorance about the problem at hand.

Other important Smart City issues

- Smart cities development & deployments announced without any groundwork on preparedness of the stakeholders and the ecosystem…
- In a smart city, multiple utilities are going to leverage and deploy similar technologies & solutions to improve the operational efficiency
- The technological trends in "smart Homes", "Smart Buildings", "Smart Grid" "Smart Water" "Smart Transport" and "Smart Cities" are being considered and pursued in isolation from each other, by the respective stakeholders. This is in spite of the fact that they form a very tightly interwoven and homogenous confluence of similar technologies being applied in different domains for a common cause of making our planet earth "smart-n-green".
- There is no common framework and architecture defined for the various physical infrastructures to be deployed in the proposed smart cities to work in an integrated, harmonized and optimized manner…
- Since, there is NO standardization or Harmonization groundwork undertaken to cater to the physical infrastructure's comprehensive and heterogeneous needs of the smart cities, most of the systems & solutions deployed shall have to be procured which are76

based on respective vendors' proprietary technologies with limited or NO interoperability with system/solution components from other vendors.

- ⇨ Each city shall always be dependent on the respective vendors throughout the lifecycle of such systems/solutions for their Operation & Maintenance, and more so for their up gradation…
- ⇨ Lack of harmonized standards in the respective "SILO" ecosystems of the Smart Infrastructure shall ensure that the smart nodes of one network cannot talk to smart nodes of the other networks.
- ⇨ Thus, Data sharing amongst the multiple stakeholders of a smart city shall be a major challenge.

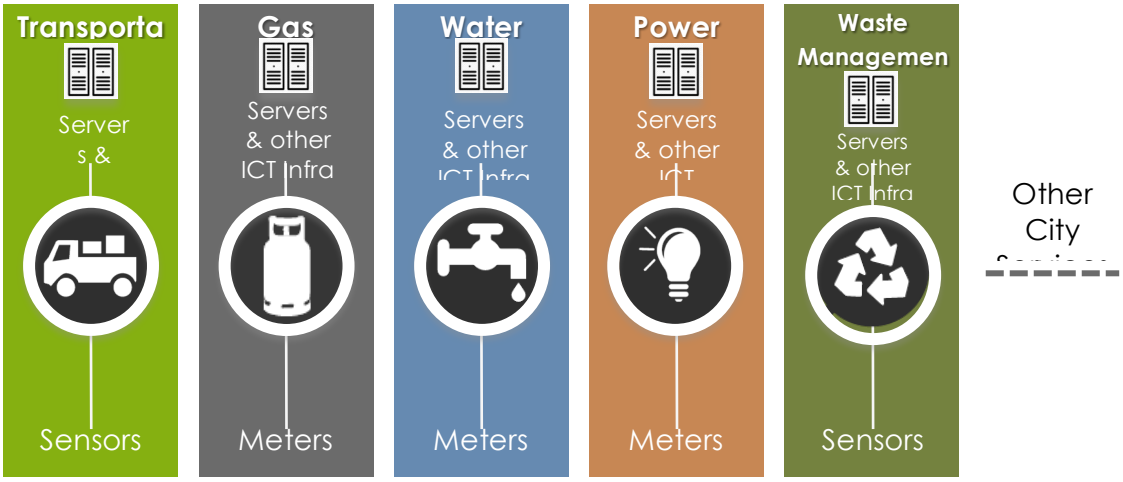
In fact, there is a recursive cycle to the data in a Smart City. Information that is generated is information that is consumed and then cycle repeats.

Application Domains Landscape

A City is a collection of as many vertical domains as one can imagine. However in view the core value of improving the quality of life for the inhabitants of the city in terms of what is important for human life as well as aligning it with the focus and thrust of the Smart City Mission of Government of India following verticals have been given prominence. These are as under

- Water
- Energy
- Waste Management
- Transportation
- Surveillance
- Connectivity
- Command & Control Centre

Current Applications live in silos



Creating a common visibility of interrelated issues –

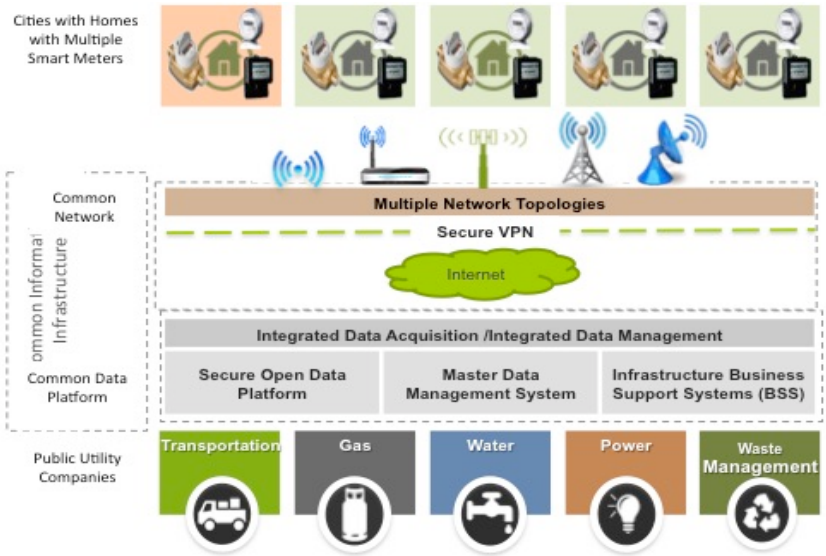
More often than not creating a uniform visibility of various issues among the consuming, service providing and governing stakeholders reduces creation of multiple lines of communication and resultant cacophony and noise. At present such platform, which can create inclusive visibility of issues, resolution plans and efforts are also multipoint and vertical specific. Additionally due to vertical implementation there is lack of transparency and resultant mistrust, suspicion, dissonance and scope of manipulation and corruption. This lack of transparency in what is transpiring within a silo extends both to consumer and to governance layer and strengthens the manipulative element within the vertical domain.

Interoperability among the cross domains –
Once even when a common visibility can be obtained, there can be several issues which are sufficiently structured, that automation and cross domain integration can be achieved and thus delays inherent to manually intervened actions can be avoided and greater operational efficiencies achieved.

Lack of inclusiveness for citizen in interaction, planning, execution and Governance –
In the area of Internet, mobility and media coverage digital citizens are no longer passive recipients of results of decisions taken in relative isolation and actions that follow from such discussion. It is observed that applications often interact with immediate stakeholders, which are directly related to that particular domain, and not with those who may be indirectly affected by the actions taken in domain. This needs to go up drastically as it has been observed in various studies that no amount of physical infrastructure can compensate for the co-operation and participation of citizen in particular program for its effective implementation. This can greatly be improved by creating those elements within the Smart City applications which ensure the inclusiveness of the citizen in the interaction, planning, execution and Governance which in effect gives citizen not only a voice but a voice which can be calibrated and measured to judge the mood and aspirations of the citizens.

The way forward: Unified Architecture

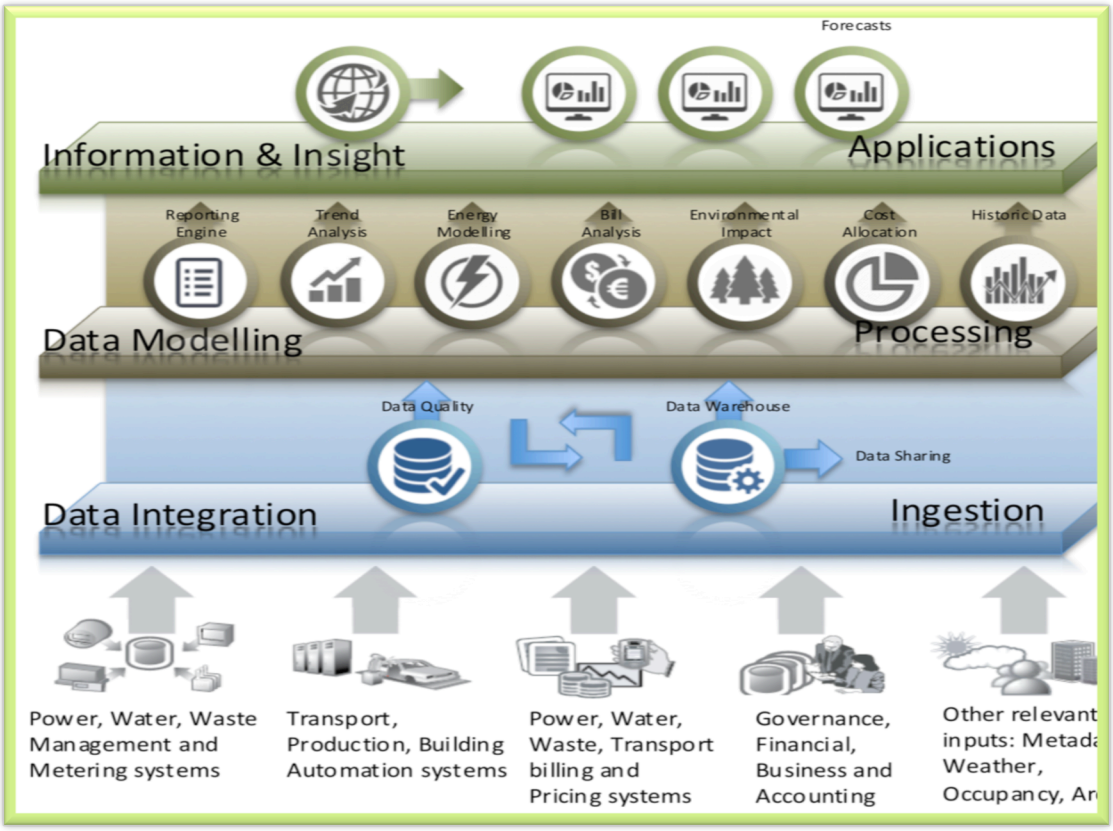
From a siloes approach to a converged common ICT infrastructure pool - Coordination, collaboration and harmonization can be better implemented by the effective use of open, common and shareable, information and communication technologies that allows the creation of a truly interconnected system with seamless communication between services. Even though the services and applications can be diverse, they could leverage the use of common infrastructure to achieve this objective.



Integrated Management for common visibility of interrelated issues –
At its very foundation, it will integrate with and ingest data from all possible sources, then apply various data models, processes and tools and ensure quality with an aim to provide insight and intelligence on various city resources and services while at the same time establishing a sharing and serving mechanism for all information resources and services in the city.

Different sources of information can blend together, in some ways compensating their own

deficiencies, enriching the larger information pool and therefore providing the ability to offer services more efficiently. A drill down of the above is depicted in the illustration below.



Interoperability for Smart Cities

ICT Infrastructure

As amply illustrated above, at present various City systems exist in their own vertical silos. This also results in each authority that is owner of a vertical system, needing to develop their End-to-End system from ground up, specifically at physical and network level and eventually at Application level.

Issues

Silo based approach and lack of common ownership –

Thus there is a great deal of redundancy as well as duplication of effort. This drives up the cost in terms of both capital and operation expenditure, drives down system efficiency, reduces systems resilience to change and weakens the effort of repair and maintenance in upkeep of various systems as that do gets duplicated.

Heterogeneity of Technology and Protocols at edge systems –

At present, systems automating a particular domain operate in functional silos. Each may have its own specific dedicated controls and networks of sensors, hardware and software, operated by companies with specialist knowledge of that particular field.

Due to vertical centric development there is a great deal of heterogeneity of technologies (though not always unnecessary) and protocols at physical, data link and network level. There are issues of Technical and physical interoperability, which creates inflexibility in terms of

vendor dependence and often to technology, obsolescence.

Idle capacities –

Often when a system dedicated to one vertical (Silo'd) is developed it has lot of redundant capacities, which remain unutilized due to the nature of the domain it address. There is a need for the standardization of the platform to promote interoperability that enables the provision of services to citizens and at the same time the sub-system are simple and plug and play. This will help cities, municipalities to scale up the platform system for future requirements.

Standardization and Interoperability of platforms/system is must when there are different solutions coming from different service providers / product manufacturers and System Integrators and when we also support the need of different solutions that cater to Smart City requirement. Standardization also ensures that services offered for the Smart Cities are reliable, scalable, secure and efficient. The major objective that is expected by the Smart City Platform are

- ⇨ Compiling the information of city, citizens and adhering to the privacy and local government policy
- ⇨ Secure access to information across the different services
- ⇨ Interoperability among the services
- ⇨ Standardized Interface to enable the development of Application for Smart City Services
- ⇨ The services should add value to quality of life of the citizens

The Smart City platform should focus on the inter-operability enabling exchange of information and inter and intra operations between different services of Smart Cities. This will enable the Smart City Managers to understand

- ⇨ Real time situation of the given cities and activate decision based on the real time situations
- ⇨ Coordination among the city maintenance managers in case of emergency situation
- ⇨ Provide real statistics of the usage of service offered by the platform and scaling up and down based on the requirement
- ⇨ Service Quality Management
- ⇨ Building healthy competition and providing equal opportunities among the different service providers in the Smart City scenario

Objective of Inter-operable Platform

The interoperable platform will be able to support and perform the following requirements

- ⇨ A transversal solution that serves as a basis for the existing and future city systems.
- ⇨ Enabling the integration of information from different systems/solutions and devices.
- ⇨ Enabling the management and operation of the different smart city projects deployed on the platform.
- ⇨ Capable of being integrated with the existing city services and platforms.
- ⇨ Enable knowledge management of the different city services both horizontally and vertically.
- ⇨ Take Preference in all Interface Reference Points the use of consolidated market standards.
- ⇨ Support and be based on market standards to guarantee interoperability with applications and their reuse.
- ⇨ Guaranteed scalability as the volume of information increases, ensuring modularity so to be capable of adapting to future functions.
- ⇨ Capacity to integrate a large amount of information generated by multiple sources and with different structures.
- ⇨ Ensure the integrity and security of data, platform and interfaces.
- ⇨ Enable the efficient analysis of the data and events managed by the platform for

decision-making and understanding behavior in the city.

- ⇨ Afford agents (public managers, providers, citizens, etc.) the tools required to increase efficiency, sustainability and quality of services.
- ⇨ Facilitate the development and integration of services and applications provided by external bodies (Third Parties) by offering APIs based on standards to interact with the platform.

Smart City Developmental Imperatives:

National Smart City Mission under Ministry of Urban Development has initiated extensive programmes for improvement of Urban Infrastructure in India and has it's own perspective as to Smart Cities needs priorities.

However, the members of the Panel on Smart Infrastructure have identified the following imperatives to ensure efficient, sustainable & secure Infrastructure with most optimized Life Cycle Cost to act as the foundation for the upcoming smart cities:

- ⇨ Common ICT physical infra
- ⇨ Framework & Architecture
- ⇨ Harmonization of standards, interfaces
- ⇨ Unified last mile communication protocol
- ⇨ End to End interoperability
- ⇨ End to End security in the signal path
- ⇨ Unified Data Semantics & Ontology
- ⇨ Integrated Management Centre

It is understood that all these imperatives can be comprehensively addressed by following the paradigm of Unified Secure & Resilient ICT Backbone based on Open Global Standards to ensure the vendor agnostic, technology neutral, scalable ICT Architecture in Smart Infrastructure deployments.

Study - PART 2 - Section1

Task Group Report

on

Technical Requirements Analysis

of

Last Mile Communication for

M2M/IoT Applications

Standardization Imperatives for Last-mile Communication:

It is now a well-accepted fact that the Silo'd way of deploying the IoT/M2M infrastructure is leading us nowhere, and we definitely need a standardized harmonized **Common Last-mile Communication Architecture** approach to tackle the problem. In a Smart City scenario, such approach is nothing less than essential, as only this would enable true interoperability between divergent devices as well as applications while maintaining identity and access control. Along with this, the sharing of data with ensured security and privacy becomes a practical feasibility.

The extensive work done by various global SDOs has very comprehensively defined the frameworks and roadmap for future ICT Infrastructure. However, the new paradigm of "Internet of Things" has given rise to a new aspect of the way human, machines and things are going to communicate with each other in the very near future.

Internet of Things is all about "heterogeneous" and "aware" devices interacting to simplify people's life in some way or the other. The heterogeneity of the IoT paradigm has made it imperative to have a fresh look at the prevalent architectures and frameworks of the ICT infrastructure being deployed or being developed.

The IoT value chain is perhaps the most diverse and complicated value chain of any industry or consortium that exists in the world. In fact, the gold rush to IoT is so pervasive that if you combine much of the value chain of most industry trade associations, standards bodies, the ecosystem partners of trade associations and standards bodies, and then add in the different technology providers feeding those industries, you get close to understanding the scope of the task. **In this absolutely heterogeneous scenario, coming up with common harmonized standards is a major hurdle.**

Hence, true convergence is still eluding the evolved citizens of today's super industrial society, because of lack of harmonized standards in the respective ecosystems of Smart Homes, Smart Buildings, Smart Grid and Smart Cities. The smart nodes of one network cannot talk to smart nodes of the other networks. Multitude of 'proprietary systems/solutions', or 'systems/solutions with very limited interoperability' are being deployed in each application areas for today's Home Automation, Building Automation, Industrial Automation or even the Infrastructure Automation needs of the society. This is definitely going to ensure that we shall not be able to derive the maximum benefits of these technologies, whatsoever.

Consider the following:

A major disconnect which has recently become apparent is: the technological trends in 'Smart Homes', 'Smart Buildings', 'Smart Cities' and 'Smart Grid' are being considered and pursued in isolation from each other with 'silo' approach, by the respective stake holders. In fact, they form a very tightly interwoven and homogenous confluence of similar technologies being applied in different domains for a common cause of making our planet earth 'smart, green and secure'. Each application ecosystem like smart home, smart building, smart street lighting and smart grid have, over the years, developed their own respective sets of standards and last-mile communication protocols. Even some ecosystems like smart grid and smart home have got multiple sets of standards and protocols being advocated as the most appropriate for their respective applications. Unfortunately, all these initiatives, protocols and standards go against the tenet of the unified and harmonized paradigm of the Smart Infrastructure.

A Case in Point:

In a smart city, a Data Concentrator Unit/Gateway is installed at a main square of a city, with RF range of 200 meters radius. Does it make sense to dedicate this DCU/Gateway for only one application like Smart Street Lighting only? Should we not leverage this DCU to communicate with all kind of sensors or smart "monitoring and/or control" nodes within a radius of 200 meters irrespective of their applications or use cases, and collect the data from them and send it to the cloud/server, where the data is segregated on the basis of their applications or use cases and forwarded to the respective stakeholders' databases? The importance of a sound & vibrant unified ICT backbone in making the concept of any smart city cannot be underscored.

Another Case in Point:

At the lower layer of smart nodes themselves, take an example of the electricity energy meter. Earlier, there used to be a single stakeholder of the data from the energy meter; and that was - the 'Utility' supplying the Electricity, and that also, only because the utility needed the data, so that it could raise the bill against each consumer in accordance to the individual energy consumption. Today, the same 'energy meter' has three different stakeholders of the data from it: First is still the Utility, as it still needs to raise the bill. Second stakeholder is the consumer. Today, each consumer wants to monitor his own energy consumption and its pattern to manage his energy bill or even devise his energy efficiency strategy. Third stakeholder is the Building Energy Management System, be it a residential or commercial building (unless of course, if the consumer is living in an Independent Villa etc.). The BEMS needs the data from each consumer's energy meter to understand and thus manage and cater to the needs of each consumer efficiently, and reliably.

Incidentally, all these three ecosystems have evolved in a Silo mode, and developed and adopted different communication technologies and protocols. The utilities have adopted DLMS or ANSI Tables as its Data Exchange Standard. Home Automation ecosystem uses ZigBee or KNX technologies and protocols, and the building automation or management ecosystem has been using MODBUS as its communication & Data Exchange platform.

So, shall a consumer deploy three different meters to share information with the three stakeholders? Or, a consumer shall put three communication modules on a single meter to share the data individually with each stakeholder? Neither is a truly viable solution. Thus, there is a dire need to harmonize the communication technologies and protocols, as well as, data exchange formats to share the energy meter data with multiple stakeholders.

UNIFIED Data Semantics Imperative

- ⇨ The recent and even current focus to achieve the Semantic interoperability has been thru APIs & Common Data & Information Models mapping the Ontology Databases of both applications/standards, or writing Interworking Proxies...
- ⇨ This is achieved on the upper layers of information exchange without any harmonization at the Bottom Layer of the Application Data Semantics…
- ⇨ Every SDO or Industry Consortia has developed their individual sets of Data Semantics & Ontologies, and interestingly are even today, continuing to do so…
- ⇨ It implies that if any vendor wants to develop the same product for multiple applications, he shall need to customize it for each application, leading to multiple versions of the same design, undue additional development & inventory costs; leading to a fragmented

market, and, in turn increasing the product pricing for end users…

Who owns the Data Semantics???

The real question is that who OWNS the Data Semantics – The Communication Protocols, or, the Products themselves???

Rather than maintaining the dictionaries, directories & data bases of Data Semantics & Ontologies of various competing, conflicting and/or overlapping Standards, and then developing Common Information Models and Interworking Proxies etc. it shall be prudent to undertake a comprehensive exercise for once to develop an exhaustive list of the **Unified Data Semantics** and motivate all the stakeholders of various Ecosystems to adopt them for holistic harmonization…

There are numerous such use cases in every application domain of the smart Infrastructure deployments. If the standardization, harmonization and interoperability aspects of the critical information and communication infrastructure are not addressed immediately, then we shall end up investing many times more on implementing the current initiatives of the governments, which shall become redundant in next few years, when (and if) the stakeholders of all the various ecosystems come up with the harmonized and interoperable standards, needing reinvestment of taxpayers money to revamp the infrastructures.

The Imperative:

Smart projects are often connected to other aspects of infrastructure, and should be thought of as large systems-of-systems, the success of which relies on the optimization of all the sub-systems that support it. Some of the earliest deployments of smart infrastructure have proven to be not so smart. Most deployments have failed to identify dependencies or interactions with adjacent systems, impacting overall performance and restricting functionality.

Such a systems level approach in design and standardization is likely to not only enable newer and better services, but also allow far greater synergies and cost-effective deployments, reducing the lifecycle (total) cost of ownership of any Infrastructure, be it the grid, a home, a building or even a city, with attendant environmental benefits, including carbon reductions.

There is a need to focus on the creation of a secure, standardized and open infrastructure model for the delivery of services. The concept combines standards-based, end-to-end software with a converged smart infrastructure gateway/DCU design to establish a common, open framework for secured service delivery and management.

"A 'box' (or service gateway) built on such a platform can consolidate boxes from utilities and/or multiple service providers into a single, unified BOX that can support multiple service providers and utilities. In wake of the proliferation of 'IoT', a new paradigm of "Fog Computing", beyond the "Cloud Computing" is evolving rapidly. In this paradigm where the storage and intelligence moves from the "cloud" to the "edge" the standardization, harmonization and the interoperability take a pivotal role for operational efficiency of the "Smart Infrastructure".

This approach, if adopted to define the framework and architecture for Smart Infrastructure, shall lead to tremendous savings and optimisation of CAPEX & OPEX of the "Smart, Sustainable & Secure Cities", as well as lead to unprecedented reduction in the 'Carbon Footprint' of the ICT Infrastructure in any earmarked geographical territory.

The major focus of the proposed exercise must be to develop and deploy such a unified, harmonized and yet standards based Comprehensive "end-to-end last-mile communication protocol" defining explicitly and comprehensively layer by layer, frame by frame with complete interoperability, be it at the network, semantic or at syntactic level.

It is hoped that if such a solution could be developed, it could be used as a reference framework for development of standards in the field unified communication for 'Smart City' and 'Smart Infrastructure'.

Smart Cities & Smart Infrastructure:

Beyond leveraging ICT in the digitization of Institutional, Economic, Social & Governance Infrastructures of a city, a glimpse into the physical infrastructure brings out a few staggering numbers on the business aspect of this Unified & Secure ICT Infrastructure paradigm and its intervention in a smart city. Consider the scenario in India, as an example:

- ⇨ Smart Cities or NOT, In next five years, more than 250 million Smart Electricity Meters are going to be procured & deployed under the NSGM (National Smart Grid Mission). All these 250 million Smart Meters are going to use Communication Modules and Gateways/DCUs (Data Concentrator Units). At a conservative figure of One DCU/Gateway to 500 Smart Meters, 250 million Communication Modules & 0.5 million DCUs/Gateways shall be needed for the last mile communication in the Smart Grid Deployments alone…
- ⇨ Smart Streetlights in next five years, are going to use more than 100 million Communication Modules and at least half a million of DCUs/Gateways…
- ⇨ Smart Buildings are going to deploy more than 50 million smart Sensors and at least 100K – 200K DCUs/gateways…
- ⇨ Similarly, various applications of the Smart Infrastructure paradigm like Smart Water, Smart Gas, Smart Traffic, Smart Environment, Smart sewage Disposal etc. are going to use a few billions of Smart Sensors with Communication Modules and DCUs/Gateways correspondingly with at the least worst case ratio of 1:100 to 1:500….
- ⇨ Even if, the unified Communication Infrastructure is deployed, the number of sensor Communication modules is not going to reduce; only the DCUs/Gateways needed shall reduce, but shall need enhanced features and design complexities…

To summarize, India ALONE, is going to need a minimum of 8 - 10 billion Communication modules to be integrated into the Smart Sensors and Controllers and 10– 50 million Gateways that shall be needed to operate and maintain the Nation Wide Critical Infrastructure that needs to be deployed to enable and empower the citizens to lead a sustainable, safe and secure life …

With the current practices of Silo'd deployment of utilities' ICT infrastructure on divergent technologies, protocols and standards, along with lack of interoperability, the market shall also remain fragmented. However, development of a unified comprehensive standard shall consolidate the market and drive down the costing of the communication modules and Gateways and hence ease the Capex constraints on the Smart Infrastructure deployments.

The Study:

As enumerated above, following the Systems approach methodology; a two-fold approach has been taken in this study to cover the three aspects of – Market/Industry Analysis, Stakeholders Analysis & Use Cases Analysis:

1. Study of application use-cases with respect to their broad technical requirements.

2. Study of the technical requirements with respect to three deployment models.

Numerous SDOs and Industry Consortia have already compiled the Applications/Use Cases for Smart City/Infrastructure. Hence, the Task Group decided to review & analyze them rather than creating a fresh listing.

After review of all the use cases and applications in the Smart Infrastructure Domain, the following application areas were short listed for detailed analysis on the basis of importance, diversity and criticality etc.:

- Energy
- Water,
- Waste Management
- Intelligent Transport System – Smart Parking, Traffic Congestion Management…
- Manufacturing, SCADA & Industrial Automation
- Health – Active Assisted Living
- Agriculture
- Environment
- Smart Homes & Buildings

Mapping the Applications/Use Cases to Technical Requirements

The application categories in the smart infrastructure domain are quite broad and have varied deployment requirements for achieving the desired goal, which could either be:

- Monitoring,
- Control, or
- Planning.

For a systematic analysis, they were abstracted into:

1. **Coverage area (span of the physical space)**
    1) Small => 100 m
    2) Medium => 1km
    3) Large => 5km or more

2. **# Sensors (number of sensor required to cover the physical space)**
    1) Small => 100
    2) Medium => 1,000
    3) Large => 10,000

3. **Data traffic flow (amount of data moving across the network at any given point of time)**
    1) Bursty: high data rate transmission over a short time period

2) Periodic: data sent at regular intervals
3) Continuous: data sent in a continuous manner

4. **Data traffic volume (rate of data traffic flow)**
    1) Trickle => Bytes/sec
    2) Medium => KB/sec
    3) Large => MB/sec

5. **Latency (delay in data communication over a network)**
    1) Real-time
    2) Near Real-time
    3) Offline

Please refer to Appendix – I for additional details.

Summary of Observations:

1. In each application category, monitoring and control uses-cases need NEAR-REALTIME guarantees; while planning use-cases can be addressed OFFLINE.

2. The physical coverage area of the scene is directly proportional the sensor count and density.

3. Bursty data traffic is preferred for use-cases that do not need periodic/continuous feeds, but react to a change (i.e., an event) in the physical space (such as smart parking)

4. For periodic data feeds, most application use-cases would need to sample once every 15 mins; except for use-cases in the application category of energy where events are much more dynamic.

5. The traffic volume will mostly be in the KB/sec or lower range for applications that use non-visual sensors.

Mapping the Deployment Models to Technical Requirements:

After comprehensive study of all the diverse use cases and applications in the Smart Infrastructure Domain it was concluded that the following 3 deployment models could represent all applications under consideration:

1. **HAN:** Home Area Network

2. **NAN:** Neighbor Area Network

3. **FAN:** Field Area Network

The study also gave the insights into the main entities in a network design and their respective characteristics that need to be analyzed for each use case/application to understand the granular requirements from the communication technologies, protocols and/or standards that are most suitable to each of them.

Given below is brief summary of the 3 entities in a network design and their respective relevant

characteristics:

- **Device**
  - Type
    - End Node
    - Range Extender
    - Router
    - Gateway
  - Power Source (per device type)
    - Battery
    - Line
  - Battery Life Time (years)
  - Security
- **Communication**
  - Frequency Band
  - Max. Range
  - Max. Power
  - Max. Data Rate
  - Security level
  - Available Technology / Profiles / Protocols
- **Network**
  - Topology (point-to-point, star, mesh, tree)
  - Packet Size
  - Degree of Reliability
  - Stack view:
    i. Network Layer IP vs. Non-IP
    ii. Routing Layer (Distance Vector v/s Link State)
    iii. Transport Layer (Connection v/s Connectionless)
    iv. Application Layer & Messaging Technology (Broker vs. Non-broker based)
  - Security

Please refer to Appendix – II for additional details.

Summary of Observations:

1. While there are heterogeneous technologies at the PHY layer; there seems to be limited (and more widely used common) options for layers above it. It is worth coming up with a standard, unified view for all remaining layers of the last-mile stack.
2. Security is an open challenge at all levels; and needs to be looked in a comprehensive, inclusive manner.

Communication Requirements Template:

During the study the Task Group also identified the General and Specific Requirements that need to be reviewed when trying to analyze the suitability of any communication technology, protocol or standard for any particular application or use case.

General Requirements	Specific Requirements	Appropriately or Inappropriately addressed
Time Sensitivity	Delay / Latency	
	Delay Symmetry	
	Time Synchronization	

Network Architecture	Number of nodes	
	Distance (Range)	
	Capacity	
	Centralized	
	Decentralized	
	Unicast	
	Multicast	
	Broadcast	
	Topology	
	Media Dependency	
	Localization	
	Virtualization	
Network Traffic	Symmetry / Asymmetry	
	Communications Initiatives	
	Payload	
	Coexistence	
Dependability	Reliability	
	Acknowledge	
	Availability	
	MTBF	
Power & Energy	Energy Efficiency	
Adaptability	Self-Forming	
	Self-Healing	
	Mobility	
	Multi Protocol Operations	
Compliance	Environmental	
	Regulatory	
Trust	Security (CIA)	
	Privacy	
	Safety	
	Functional Safety	
Other	Cost Constraints	
	Interoperability	

Annexure I

Sr. No.	Application Category	Application Use Case	Coverage Area
			Small => 100 m
			Medium => 1km
			Large => 5km or more
				# Sensors
				Small => 100
				Medium => 1,000
				Large => 10,000
					Data Traffic Nature
					Bursty
					Periodic
					Continuous
						Data Traffic Volume
						Trickle => Bytes/sec
						Medium => KB/sec
						Large => MB/sec
							Latency
							Real-time (us)
							Near Real-time (ms)
							Offline

1	ITS	Smart Parking	Medium	Medium	Bursty	Trickle	Near Real-time
2		Traffic congestion management (traffic monitoring & control) - video based	Large	Medium	Continuous	Large	Near Real-time
3		Traffic congestion management (traffic monitoring & control) - non-video based	Large	Large	Periodic (1 min)	Medium	Near Real-time
4	ENERGY	Grid monitoring and control	Medium	Medium	Periodic (1-15 mins)	Medium	Near Real-time
5		Peak load management	Large	Large	Periodic (1 min)	Medium	Near Real-time / Offline
6		Smart metering	Large	Large	Periodic (30 min)	Medium	Near Real-time / Offline
7		Micro-grid	Large	Large	Periodic (30 min)	Medium	Near Real-time / Offline
8	WATER	Drinking water - Water quality monitoring	Large	Medium	Periodic (30 mins)	Trickle	Near Real-time / Offline
		Drinking water - Treatment plant automation	Medium	Medium	Periodic (5 Mins)	Medium	Real Time
9		Waste water treatment - Water quality monitoring	Large	Medium	Periodic (30 mins)	Trickle	Near Real-time / Offline
		Waste water treatment - Treatment plant automation	Medium	Medium	Periodic (5 mins)	Medium	Real Time
		Pipe leakage detection	Large	Medium	Periodic (05 mins)	Trickle	Near Real-time / Offline
		Smart metering	Large	Large	Periodic (60 mins)	Trickle	Near Real-time / Offline
		Water distribution management	Large	Medium	Periodic (30 mins)	Trickle	Near Real-time / Offline
10		Pumping Station Management	Small	Small	Periodic (5 mins)	Trickle	Real Time
11		Reservoir Management	Medium	Small	Periodic (60 mins)	Trickle	Near Real-time / Offline
12		Ground Water Hydrology	Large	Large	Periodic (60 mins)	Trickle	Near Real-time / Offline
13		Pump management	Small	Small	Periodic (5 mins)	Trickle	Near Real-time / Offline
14	MANUFACTURING	Machine automation	Small	Small	Periodic (10 sec)	Medium	Real-time
15		Process automation	Large	Large	Periodic (10 sec)	Large	Real-time
16		Factory automation	Large	Large	Periodic (10 sec)	Large	Real-time
17		Industrial energy management	Large	Medium	Periodic (10 sec)	Large	Real-time
18		Predictive maintenance and diagnosis of factories, processes and plants	Large	Large	Periodic (10 sec)	Large	Real-time
19		Predictive maintenance and diagnosis of machines	Small	Small	Periodic (10 sec)	Large	Near Real-time
20	OTHERS	Environment Monitoring	Large	Large	Periodic (30 mins)	Trickle	Near Real-time / Offline
21		Waste management	Small	Small	Bursty	Small	Near Real-time / Offline
22		Smart home	Small	Small	Periodic (1-60 mins)	Trickle-Large	Near Real-time
23		Assisted living	Small	Small	Busrty- Continuius	Trickle-Large	Near Real-time / Offline

Annexure II

		Home Area Network (HAN)	Neighbour Area Network (NAN)	Field Area Network (FAN)
	Application Use Case	Smart homes | Assisted living	Factory automation | Predictive maintenance and diagnosis of factories, processes and plants |	Process automation | Factory automation | Industrial energy management | Grid monitoring and control| Peak Load Management | Smart Parking | Environment Monitoring|
Technical Requirement Mapping				
Device	**Type** (End Node, Range Extender, Router, Gateway)	End Node, Range Extender, Gateway	End Node, Range Extender, Gateway	End Node, Router, Range Extender, Gateway
	Power Source (per device type) (Battery, Line)	End Node (Battery/Live Power), Range Extender (Live Power), Gateway (Live Power)	End Node (Battery/Live Power), Range Extender (Live Power), Gateway (Live Power)	End Node (Battery/Live Power), Router (Live Power), Range Extender (Live Power), Gateway (Live Power)
	Battery Life Time (years)	10 Years	10 Years	10 Years
	Security	TPM / Secure elements/embedded sim / UICC device security MAC module for COM	TPM / Secure elements/embedded sim / UICC	TPM / Secure elements/embedded sim / UICC
Communication (wireless)	**Frequency Band**	2.4GHz, 433MHz, 866MHz, 5.8GHz	866MHz, 2.4GHz, 5.8GHz	866MHz
	Max. Range	10-50 Meter	50-100 Meter	100 - 5000 Meter
	Max. Power	14dBm	20dBm	30dBm
	Max. Data Rate	10Kbps - 1 Mbps	10Kbps - 1 Mbps	10Kbps - 1 Mbps
	Security level	Low - Medium	Medium - High	High
	Avaliable Technology / Profiles / Protocols	Zigbee, Thread, Wi-SUN, Wi-Fi, Bluetooth, PLC, Ethernet, Z-Wave, BacNET	Wi-SUN, Wi-Fi, Ethernet, PLC, Zigbee	Wi-SUN, LoRA
Communication (wired)	**Avaliable Technology / Profiles / Protocols**	Ethernet, ModBUS (RTU & TCP), CANOpen, Profinet, Profibus, DeviceNet, Ethernet IP, Ethernet PowerLink, Sercos, EtherCAT		
Networking	**Topology (point-to-point, star, mesh, tree)**	Star/Tree/Mesh	Star/Tree/Mesh	Star/Tree/Mesh
	Packet Size	upto 512Bytes	upto 512Bytes	2047 Bytes (to support complete IP frames)
	Degree of Reliabilty	Low - High	Low - High	Medium - High
	Stack View			
	: Network Layer IP vs. Non-IP	IP	IP	IP
	: Routing Layer (Distance Vector vs. Link State)	Distance Vector	Distance Vector	Distance Vector
	: Transport Layer (Connection vs . Connectionless)	Mandatory: Connectionless Optional: Connection Oriented	Mandatory: Connectionless Optional: Connection Oriented	Mandatory: Connectionless Optional: Connection Oriented
	: Application Layer & Messaging Technology (Broker vs. Non-broker based)	Application Specific	Application Specific	Application Specific
	Level of Security	Low - Medium	Medium - High	High

Conclusion:

The "last-mile" communication technologies will need to connect heterogeneous devices with heterogeneous applications. A unified last-mile stack will enable the necessary interoperability across all such devices (irrespective of the diversity in the PHY and Link-Layer Technologies) and offer a seamless view to the application. It should also allow connectivity to existing infra-structures and to the Internet. In this regard, we need to thoroughly access the suitable candidate technologies, protocols and standards for unification of the last-mile communication for Smart Infrastructure needs.

Through a common network-layer protocol**, IP-based "last-mile"** architecture will enables interoperability at the levels:

- ⇨ Among heterogeneous link-layer technologies such as IEEE 802.11, IEEE 802.15.4, Cellular, Bluetooth or Powerline Communication (PLC) etc.; and
- ⇨ Among heterogeneous applications such as web-based configuration systems, publish-subscribe protocols, etc.

IETF has already defined the 6LoWPAN (IP-v6 Low-power PAN) Adaptation Layer, which integrates IP-based Infrastructures and heterogeneous "last-mile" field devices by specifying how IPv6 packets are to be routed in constrained networks (such as the IEEE 802.15.4 network). We recommend that 6LoWPAN should be considered as a universal adaptation layer for IP enablement in the last-mile paradigm.

This study shows that there is value in unifying the last-mile communication, networking and data transfer stack for higher layers (ranging from network layer to the application layer); which would make it easier for various protocols and stacks to cross-function, irrespective of the underlying PHY and MAC layer technology.

Based on the technical requirement study and analysis enumerated above, we need to take the unification of last miles communication in Three Steps:

Layer 1 – 2:

As first step, we need to have a clear definition of Layer 1 – 2 (PHY/MAC Layer). Here the two layers are tightly coupled with each other and hence the two layers need to be defined together. We can have multiple technologies as an option at this layer. For example: IEEE 802.11 (Wi-Fi), Ethernet, IEEE 802.15.4, PLC, Cellular and many more. Based on the technical requirements study done above, user will need to choose which Layer1-2 option is suitable for their end application deployment. The selection of the Communication Technology and hence the choice of PHY & MAC layer shall depend on the parameters that need to considered for any application, use case and/or deployment scenario. Some of them being

- ⇨ RF Frequency Band to be used.
- ⇨ Maximum Range expected.
- ⇨ Frame Encryption needed.
- ⇨ Channel Access Mechanism required.
- ⇨ Maximum Data Rate needed.
- ⇨ Frequency Hopping to avoid any Channel Access Failure.
- ⇨ Transmit Power
- ⇨ Dynamic Control of Transmit Power

Layer 3 – 6:

*As IPv6 is the only way forward in the IP communication regime, we need to keep IPv6 as the basic requirement. This makes it easy to create a unified L*ayer 3 – 6 Protocol Stack. We shall need to have few components like Mesh network support, Security as different options, which can be used, based on the end application. Rest all other features and functionality can be unified for Layer 3 – 6. The unified Layer 3 – 6 should be defined in a way that it should work with any of the Layer 1 – 2 options. Here to be more specific below are some of the parameters we will need to consider as part of the protocol definition at these layers:

- ⇨ IPv6 Support
- ⇨ Mesh Network
- ⇨ Maximum number of Hops
- ⇨ IP Layer Security
- ⇨ Security Framework
- ⇨ Maximum Packet Size
- ⇨ Fragmentation/Defragmentation
- ⇨ Connection Less/Connection Oriented

Layer 7:

To achieve End-to-End Unified Stack we need to achieve interoperability in the Application Layer, as well. For this, we need to standardize the Data Semantics. As enumerated and illustrated in an earlier, this is one of the most crucial aspect to be addressed in the Smart Infrastructure domain. It has been observed that it is feasible to standardize the comprehensive set of Data Semantics for the Smart Infrastructure, if we either identify any existing or create a Framework to define a vast number of Data Semantics in a unified, harmonized and structured manner.

Hence, it is imperative that India Develops a Unified Last Mile Communication Standard in which:

- ⇨ Layer 3 to Layer 6 shall be immediately Unified and standardized.
- ⇨ For all the prevalent Communication Technologies that support IP, Interfaces between L1 - L2 and L3 – L6 shall be defined.
- ⇨ A comprehensive Framework for defining Data Semantics in a unified, harmonized and structured manner shall either be Identified (if it exists) or developed; followed by developing a Directory defining the Data Semantics for Smart Infrastructure domain.

NEXT STEPS:

To undertake the exercise of defining the unified last-mile stack based on the description summarized in the conclusion section above.

Study - PART 2 – Section 2

Task Group Report

on

Technical Requirements Analysis

of

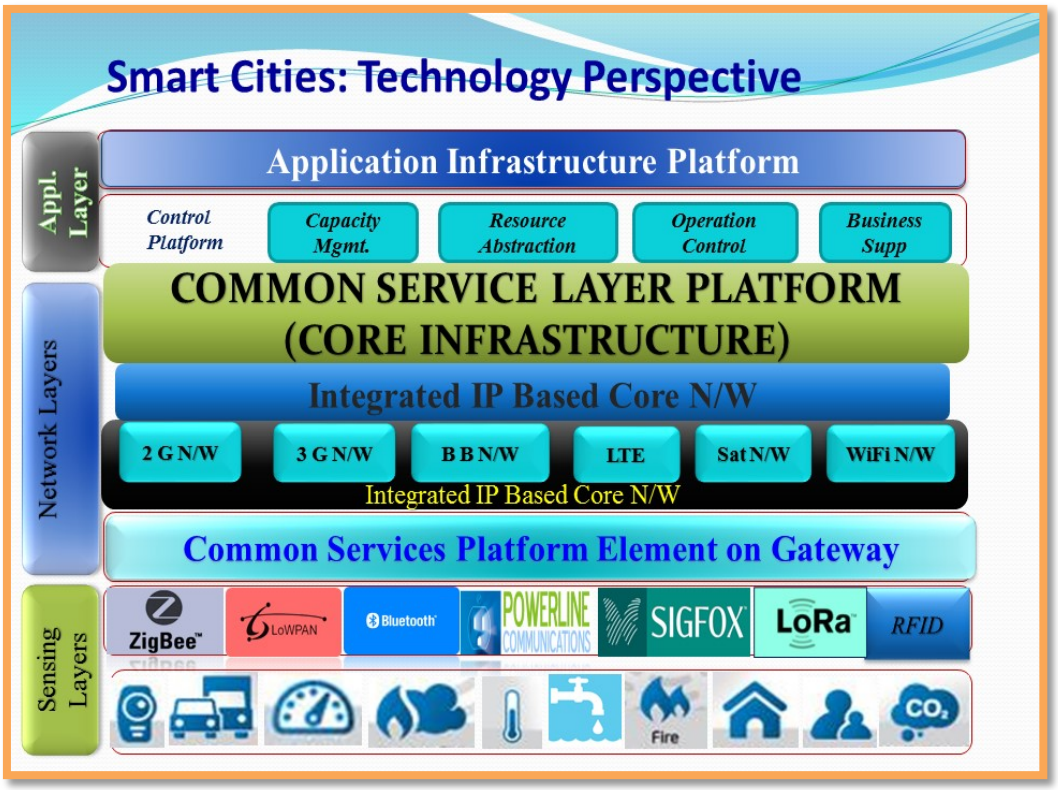
"Common Service Layer Requirements

in

ICT Architecture for Smart Infrastructure"

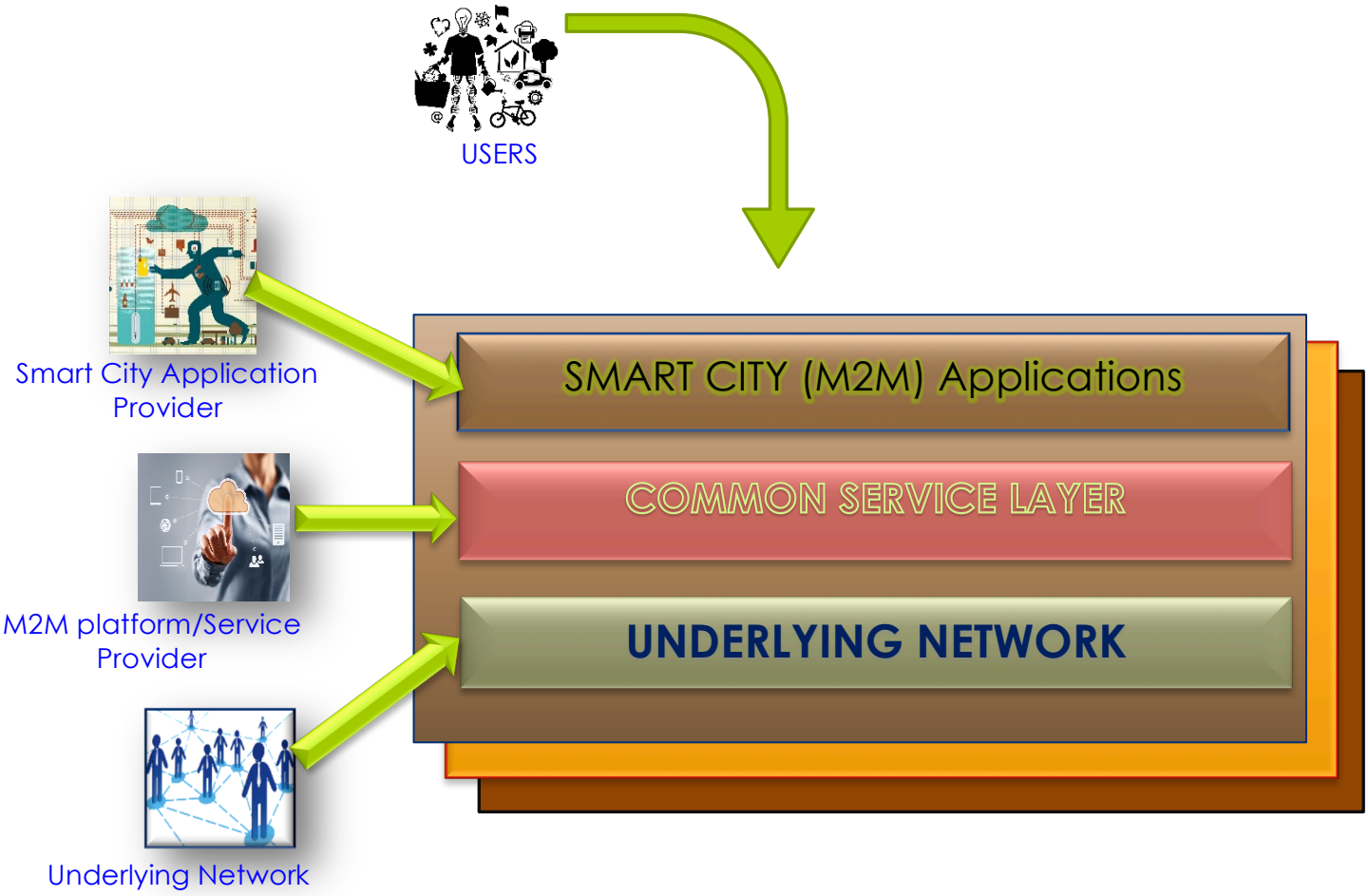
The Smart City ICT Architecture: IoT/M2M Perspective

It is now a well-accepted fact that the Silo'd way of deploying the IoT/M2M infrastructure is leading us nowhere and we definitely need a standardized horizontal **Common Service Layer** approach to tackle the problem. In a Smart City scenario, such approach is nothing less than essential as only this would enable true interoperability between divergent devices as well as applications while maintaining identity and access control. Along with this, the sharing of data with ensured security and privacy becomes a practical feasibility. A typical Smart City Architecture using the common service layer is illustrated in the figure below.



Functional Roles Description

1. The ***User*** (individual or company – aka: end-user) fulfills all of the following criteria:
   - Uses an M2M solution.
2. The *Application Service Provider* fulfills all of the following criteria:
   - Provides an M2M Application Service.
   - Operates M2M Applications.
3. The *M2M Service Provider* fulfills all of the following criteria:
   - Provides M2M Services to Application Service Providers.
   - Operates M2M Common Services.
4. The *Network Operator* fulfills all of the following criteria:
   - Provides *Connectivity* and related services for *M2M Service Providers.*
   - Operates an *Underlying Network*. Such an Underlying Network could e.g. be a telecom network.



Functional Roles in the M2M Ecosystem

Any of the above functional roles may coincide with any of the other roles. These functional roles do not imply business roles or architectural assumptions.

This Common M2M Service Layer should be agnostic to underlying network technology (yet leveraging the unique features of these underlying networks), and it will use network layer services (such as security (encryption and authentication), QoS, policy, provisioning, etc.) through an adaptation layer/APIs.

The ICT infrastructure for any Smart City shall involve TWO major components: IT Infrastructure and Communication Infrastructure. The upcoming trends are witnessing evolution of New M2M/IoT/ICT Service providers, who leverage the IT infrastructure of Cloud Service Providers and Communication Infrastructure of the Telecom Service Providers. They deploy the ICT/M2M platforms to deliver the services to multiple application needs of utilities and city administration. However, most of major Telecom Service Providers are also scaling up to deliver these services to utilities and city administrations.

Review of Technical Requirements of a typical M2M/IoT Service Provider:

A review of the typical ICT Frameworks that are being deployed by the Telecom and/or M2M/IoT Service Providers provide very explicit insights into the Requirements from any M2M/IoT platform and hence can help understand the Technical Requirements from the Common Service Layer that is the Foundation of any M2M/IoT platform.

Functional Requirements of the Solution:

Architecture Principles

The Platform shall follow the below mentioned principles in designing the architecture:

- SOA
- Multi-tenancy
- Horizontal and Vertical Scalability catering to:
  - The transactions on the platform
  - Devices
  - Data storage volumes
  - Vertical Applications
  - Support Modular scalability such that it does not degrade the performance of other components of the Architecture
- Service registry for service usage
- Service Creation Environment
- Amenable for Virtualization, DR and/or BCP
- Modular Availability as per Business Requirement (at the time of implementation and later)
- Comply Service Provider Security Policies
- Support Green Initiatives
- The Platform shall be integrated with Service Provider's SOA infrastructure.

COTS Platform

Platform/solution must capable of being System-integrated on COTS products, which can be implemented in Service Provider premises and can be seamlessly integrated with Service Provider's current operational environment. The platform shall be customizable as per Service Provider's requirements.

1. It must be capable of enabling innovative pricing and billing models for customers.
2. It must be capable of integrating with SP's CIT, SDP, Device Management, Security and other infrastructure.
3. The platform must be capable of providing a placeholder to embed business logic specific as per requirements.
4. The platform must be capable of providing a flexibility to meet multiple hosting model requirements including SP hosted and Enterprise hosted.
5. The solution must follow Future proof architecture for platform by providing following
   - Best of breed products with individual product roadmaps.
   - Pick and mix options to match SP requirements.
   - Highly reliable and scalable 'out-of-the-box' solution.
   - Flexible Service Oriented Architecture.

- Standard open interfaces for simple integration.
- Extendable to meet SP's SMB customers for application hosting (SaaS Model)

6. The solution must be robust and reliable without any downtime and performance issues.
7. The solution must be able to securely deliver the sensitive information along with anonymity support.
8. A M2M device (certified and non-certified) must be able to work with multiple applications and an application must be able to work with multiple types M2M device (certified and non-certified).
9. White and black listing central capability to prevent any unwanted access of application to an M2M device/Gateway as pre requirement of end device user against their any privacy concern. User-friendly interface should be there for its application.
10. Platform must be capable of seamless integration and must smoothly work with 3rd party applications and M2M devices.
11. The solution should provide an easy to use mechanism to view extensive and real time reports.
12. API customization must be possible based on Service Provider requirement due to internal, market, regulatory and M2M application need
13. Proposed solution must be capable of integrating to systems for fault and performance management
14. It must seamlessly work on following technologies
    - 2G
    - 3G
    - LTE and 4G
    - MPLS
    - Wi-Fi
    - Fixed line
    - ADSL latest version
    - Voice, SMS, MMS

15. Functional Requirements for integrating within Service Provider eco system
    - Adapter Framework
    - Care
    - Billing
    - Provisioning
    - Authentication and Authorization
    - Application Management
    - Customer SLA Management
    - Process Orchestration
    - Reporting/MIS

16. Technology Requirements for integrating within Service Provider eco system
    - Modularity of technologies Compatibility
    - Reliability and speed
    - Flexible architecture
    - Robustness & fault tolerance
    - Tracing and Auditing
    - Data View

17. Must Provide Portals (graphical user interfaces and APIs) for Operators and Enterprise for managing the business related processes.
18. M2M infrastructure of the platform should have compliance with 3GPP technical standards and country specific telecom regulatory/Governance guidelines.

19. Lawful interception support and architecture as per local country's government and regulatory guidelines.
20. Optimal session management support and control between devices, the platform and applications.

AAA

The platform shall provide/reuse the AAA functionality available in the Service Provider ecosystem as below:

- Authentication:
  - All SIMs and Devices shall be authenticated for being part of the network and service.
  - The Platform shall support activation and de-activation of SIMs service and account/ customer wise.
  - The Platform shall support customer authentication on Portals.
  - The Platform shall provide Single sign on functionality for enforcing security policies over a wide range of Web and application resources.
- Authorization:
  - The Platform shall support remote and bulk provisioning of SIMs, MSISDNs, and Devices etc.
  - The Platform shall support service authorization to SIMs, MSISDNs, and Devices etc.
  - The Platform shall support and authorize Enterprise relationships like Peer to Peer, Parent-child etc. on Portals.
- Accounting:

  The Platform shall support all the charging models for all the use cases- B2B, B2B2C, B2C. A few of them are listed below:
  - Event based
  - Subscription based
  - Volume based
  - Bundled

Billing and Charging

Online and Offline Billing and charging including following scenarios at least,

- Instance/event based
- Date and Time base
- Usage, volume based
- Bundled apps based
- Fixed/Flat
- Location-based
- Number of SIM cards based
- Communication channel wise
- Bundled
- Service wise
- Subscription based

Provide customized consolidate or separate bill/report for single user's multiple billing scenarios applications

⇨ Integration with payment gateway for internal and external application/services

Security Management

This shall have elements:

1. Platform/ Service Security

2. Device Security

1. Platform/ Service Security

The Solution Provider will comply with security guidelines as defined and circulated by Service Provider Information Security team from time to time.

Some of the security requirements (non exhaustive list) are as follows:

- Installing special XML firewalls for protection against attacks directed at web services as well as against conventional http services.
- Creating multiple security zones as per requirements from time to time.
- Intrusion (both physical & virtual) prevention, detection, and protection
- User Identity management including privileged identity management.
- Log management to ensure maintenance of transaction history, audit trails as well as security incident management.
- Support for multifactor authentication, authorization and access control.
- End-to-end encryption of sensitive data, both in storage as well as in transit.
- Both the platform as well as device should be able to ensure integrity of data exchanged. Unauthorized modification/ manipulation of data should not be possible.
- Secure and authenticated access to internal CIT applications, SDP as well as web services.
- Implementation of DoS/ DDoS prevention measures on all public/ Internet facing IPs.
- Password policies implementation
- Disaster management & Business Continuity
- Concurrency management

Getting periodic penetration tests & security audits done by external agencies

2. Device Security:

The Platform shall ensure device security through the following (non-exhaustive) measures:

- Support for mutual authentication wherein both the device as well as platform/ application server authenticate each other using either PKI or 3GPP authentication protocols.
- Support for Group based authentication should exist to minimize bandwidth usage when authenticating devices in bulk. While implementing group based authentication, it should be ensured that individual devices use distinct keys for authentication as well as data encryption.
- Support for hierarchical modeling of devices to allow group based authorization policies.
- Encrypted storage of sensitive/ customer privacy data on devices.
- Access to device OS/ firmware/ applications to have authentication as well as authorization controls.
- It should be possible to lock device usage to a particular M2M application such that a tampered device cannot be used to access other unauthorized services.
- Assigning Individual/ unique private and fixed I.Ps/ I.P Pool to the devices
- Implementing Alarms, alerts etc. for the physical tampering of devices

Fraud Management

The Platform/Solution shall provide a comprehensive fraud management infrastructure, which would include, among other things, a minimum of automated screening of transactions for fraud, manual review of suspect transactions etc. It shall support the requisite tools that would help prevent fraud.

21. Inventory procurement and forecast model for SIM, Device and smart Objects should be available

M2M Device and Gateway Management

The Platform shall provide Device Management functionality for the sensor devices and Mobile devices (that would host applications to transfer data to the platform) through the following:
Maintaining relational database of devices (sensor devices, mobile devices, sensors, actuators, gateways, servers, SIMs, routers etc.)
Service-wise deployment, calibration, monitoring and tracking
Support for the devices- warranty, license, certification

Inventory management

- Remote detection of failure of devices, sensors, actuators, gateways, servers, SIMs, routers etc.

Remote status/diagnostic/ configuration management

- Configuration of devices, enabling and disabling features
- Scheduling and controlling automatic software upgrades
- Fault management: Report errors from the device
- The system shall be able to configure the following settings for remote devices:
    - Modem settings (SMS, GPRS, etc.)
    - Reset modem

Mobile Device Management

- The solution shall support all kinds of handsets, OS, peripherals, Mobile terminals, Modems, Printers, Sensors, Routers and PoS devices/ terminals used to transfer data.
- The solution shall provide an easy way to debug the applications.
- The solution shall provide an easy way to port developer's existing applications on to the platform OTA.
- OS upgrades on all the handsets, OS, peripherals, Mobile terminals, Modems, Printers, Sensors, Routers and PoS devices/ terminals used to transfer data.
- Remote SIM and device lock capability
- OTA capability for all the required M2M device and gateway management
- FOTA capability support for firmware upgrade of M2M devices/Chipset
- FOTA capability should compliance with international standard like OMA, LWM2M etc.
- The system shall be able to query and configure devices remotely by sending commands using SMS, GPRS or CSD.
- The system shall allow single and batches of OTA commands to be sent in scheduled or ad-hoc manner.
- The OTA commands shall interact directly with the device's operating system or through a Device or SIM Toolkit (STK) application that acts as a remote proxy.
- The solution shall provide an easy way to port developer's existing applications on to the platform.
- The platform should store and allow monitoring all states of a transaction. Applicable states might be specific to industry.
- The system shall allow users to manually
    - Input a physical location, by entering the complete address or coordinate.
    - Input a device group in a tree structure with unlimited depth and breadth.
    - Input a device.
    - Assign a SIM card to a device.
    - Un-assign a SIM card from a device.
    - View the location of any device, in list view or map view.

- The system shall provide a batch upload function using an Excel file as input to:
    - Create devices
    - Create locations
    - Create device groups

- Assign SIM cards to devices
- Un assign SIM cards from devices

Event Collection

The Platform shall support an event collection bus that will receive all the events from the network and pass it to the inner-platform modules for further processing. It shall provide the following functionality:

- Business rule driven Event collection – Real Time/ Near Real Time/ Periodic
- Aggregation, distribution of the events data:
  - To the respective modules within platform for processing of events
  - To remotely hosted service management systems
- Adaptors for Data collection from devices, gateways etc.
- Sending acknowledgement to the devices, gateways etc. on the receipt of the event data.
- Defining the periodicity of events from the devices, gateways etc.
- Generation of alarms in case the data is not sent in the requisite time period.
- Supporting various networks connectivity, standard bearers and protocols/ interfaces:
  - Wire-line, Wireless (GSM/ WIMAX/ Wi-Fi/ LTE), Satellite (VSAT, Broadcast), DTH

Event Distribution

The Platform shall collect all the event data from the platform modules and distribute it to the devices in the field. It shall support the following functionality:

- Collection of events from:
  - Platform modules
  - Hosted service management systems
- Business rule driven Event distribution – Real Time/ Near Real Time/ Periodic
- Adaptors for Data distribution to the devices, gateway etc.
- Acknowledgement from the devices, gateways etc. on the implementation of the requisite action.

Trouble Ticketing

The Platform shall have the capability to detect, report, and provide analysis to the problems related to SIMs, Devices, and Gateways etc. This shall be a centralized/ distributed, integrated and automated system that will provide a single view to the problems in the field. This shall support (non-exhaustive list) the following:

- Identification of the problem in Real time/ Near real time
- RCA of the issue (s)
- Raising of tickets containing the requisite details of the issue (s) and RCA (s)
- Integration with the workflow management to route the tickets to the relevant people in the hierarchy.
- Supporting the trouble ticketing occurring in the network (s)- Wire-line, Wireless (GSM/ WIMAX/ Wi-Fi), Satellite (VSAT, Broadcast)

Self-Management Portals

The Platform shall provide self-management portals. These shall support the following features:

- Search, personalization, and security capabilities.
- Access to existing enterprise data, applications and to external news feeds / Web data etc.
- Support for the latest portlet open standards, including Java™ Specification Request (JSR) 286 and Web Services for Remote Portlets (WSRP) 2.0
- Templates that shall enable customers to personalize their portals and speed application deployment through new portlet development and deployment capabilities.

The above features shall be applicable on the below mentioned type of Portals:

1. Application providers/ Device Manufacturers

   Registration: The portal(s) shall enable on boarding of application providers, device suppliers etc. Some of the requirements may be (not an exhaustive list)

   - Information about the organization
   - Domain information by the device manufacturers/ application providers
   - Uploading of device information
   - Certification details
     - Certification status- completed, underway, yet to start etc.
     - Certifying body- an exhaustive domain-specific relevant list may be provided to choose from.
     - Other details
   - Calibration details of the devices
   - Call flow diagrams etc.
   - Contract management

2. Portal for Customers:

   The Platform shall provide portal for customers- Enterprise, SMB, and End-customers. This to be integrated with Service Provider's enterprise CRM and iCRM. This should also have the capability to be integrated with existing self-care portal. It shall support (non-exhaustive) the following functionality:

   - Registration of Customers:
     - Information about the organization
     - Defining business objectives
     - Segment specific portal
     - Ability to choose M2M services
     - SLA definition
     - Account hierarchies for Enterprise, SMB etc.
   - Service analysis reports and Dashboards
   - SIM Management Portal for the contracted SIMs
   - Workflow management
   - Service bills
   - Enterprise social networking
   - Mash-ups
   - Customer complaint logging and tracking

3. Portal for Customer Care:

The Portal shall provide the following information:

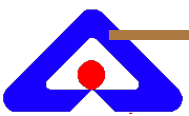
- To service the customer care calls- Enterprise and Service Provider Subscribers
- Services that the Enterprise/ Customer have subscribed to
- Billing information
- Trouble ticketing

4. Self-care portal

   (Across all bearer channels i.e. SMS, USSD, WAP, Web) for end device/user usage for relevant services and applications

Alarm Management

This refers to management of alarms under various conditions like physical tampering of the devices, surpassing of the threshold values etc. The platform shall support the following information to be taken from users through portals and mapping it with alarms:



- Selecting the alarm conditions
- Defining the threshold values
- Mapping the alarm conditions with the threshold values
- Defining alert hierarchies as per the alarm criticality
- Remote alerts to the relevant people on Web, Email, SMS, WAP, IVR etc

The Platform shall support generation of alarms basis the information provided above. Also, the platform shall support multi-layered alarm management. This functionality may be required for real time alerts.

Business Process Orchestration

This refers to building processes and information flow that can improve business effectiveness and efficiency through integration with technology. This shall be enabled through the following:

- Workflow Management

This refers to the management of the flow of information to the relevant people at the right time. This shall include:

- Defining the alert hierarchies
- Defining the roles of individuals and their hierarchies
- Defining the escalation matrix
- Mapping the alerts with the roles and escalation matrix
- Definition of Business rules and policies
- Remote alerts and approvals over SMS, WAP, Email etc.
- Follow-through action monitoring

Business Rules Engine

The Platform shall support configuration of Business rules/ policies and a user interface to capture the same. These rules/ policies shall interact with the other Platform modules to govern their working. The Platform shall allow dynamically changing of rules based on business requirements. It shall also allow users to understand how and where rule changes affect decisions within operational systems.

Payment Module

The platform shall support a payment module through which the customers- Enterprise, SMB, end-customers (B2C Scenario) etc. will make pre-paid/ post-paid payments to Service Provider in lieu of M2M services. Settlement of accounts for all such transactions shall be a part of the functionality of the Platform. The platform should also be integrated with respective business units billing /invoice generation systems like Integrated stack for enterprise and SMB etc.

Payment Security

The following basic security features shall be required:

- Authentication of parties involved in the transactions
- Data integrity throughout transmission
- Confidentiality of private information
- Non-repudiation of the parties involved in the transaction
- Acknowledgement receipt

This shall result in creating a trusted framework for all transactions between each party, be they customers, Application providers, device manufacturers etc.

APIs

There shall be API sets/ Web services for communicating and integrating with the application providers, customers etc. There shall also be APIs for integration with the CIT, SDP and other platforms like Advertisement. The Platform shall utilize current capabilities existing in Service

Provider ecosystem.

Enterprise Social Networking

The Platform shall provide social networking on the customer portals- Enterprise, SMB, and End-users etc. This shall enable them the following:

- Enable a device to be user of social network and communicate with people and machine friends
- Efficient Internal communication
- Create close communities and exchange information.
- Posting information in the form of blogs, tweets etc.
- Search ability of the posts

Mash-ups

The Platform shall support Mash-up of applications that will combine the features of two or more applications to provide a single service. This shall follow the architecture and security principles mapped with the respective applications to provide a holistic solution.

The Platform shall have a mechanism to define mash-ups and moderation capability to approve the same before it is implemented.

Reporting Module

The Reporting tool is extremely important for providing information about the platform, service behavior, monitoring & transaction details. It shall be password protected, controlled and managed. It shall follow the defined hierarchies to show reports to the relevant audience. Login sessions shall be timed out on performance and security requirements. The Platform shall provide the following functionality:

Online Reporting:

- These reports shall be provided on a real time/ near real time/ periodical basis.
- Reports catering to alarm management shall be critical

Analytics:

- Past analytics on discrepancy detection
- Predictive analytics (based on business needs)

Adhoc Reports:

- Platform shall be capable of providing adhoc reports.
- The frequency, response times etc. shall be decided later.
- An appropriate web-based tool shall be made available for adhoc queries.
- System shall be dimensionally capable of supporting adhoc queries.

Dashboards:

- Standard reports as per the KPI definition
- Business reporting
- System performance reporting
- Attributes in reference to the events collected
- Drag and drop of different attributes to create consolidated and detailed reports
- Graphical representation of the data relationships through graphs, charts etc.
- Supporting all data formats
- Dashboard distribution as per business needs

Besides the reports mentioned above, following functionality shall be made available in the tool provided:

- Login administration
- Save report templates to generate auto-reports
- Export data in the form of a CSV, xls, email etc.

Common Service Layer Requirements:

The detailed study and analysis of the comprehensive requirements of any M2M/IoT/ ICT Solution requirements, as enumerated in the above sections enables to identify Most Common Functionalities required by one and all, irrespective of the size, the scale, the applications and any other design considerations. These Common Functionalities have been combined and Termed as "Common Service Layer". The minimum common technical requirements of the Common Service Layer in any M2M/IoT/ICT Platform or Solution can be summarized as below:

1. Application and Device Registrations

From the point of view of unique identification of the devices and applications in a smart city, the devices as well as applications (data producer as well as data consumer) need to register themselves with the Common Service Layer Platform. The registration process should uniquely identify each application, whether in the field domain (close to the devices) or in the infrastructure domain. Therefore, it is expected from the platform that it gives **Registration** as a service and any application not registered with the platform shall not be allowed to communicate. Application and devices shall be able to register with the service layer entity for various services. Registration shall involve authentication or verification of credentials and creation or allocation of resources within the server process and the database.

2. Device Management

It would be necessary to manage all aspects of the deployed IoT/M2M devices in the network. Besides status updates, this should also aide the following through this device management framework which shall also be an integral part of the Common Service Layer:

a) Inventory Management
b) Diagnostics (status of the device and information pertaining to the resources)
c) Provisioning and Activation of an Individual device and also in bulk
d) Firmware/Software Management
e) Bootstrapping
f) Suspend and Resume a Device Function
g) Configuration Management

The devices shall only have clients embedded in their firmware/software or they shall be able to communicate to the device management server through a proxy entity.

3. Provisioning of Services/Applications

The new devices shall have to be on-boarded by creating new subscription in common M2M service layer and network layer. It shall be possible to activate/deactivate/suspend/resume network and service subscriptions through the common service layer.

4. Policy & Resource Management

Applications and devices shall be able to create, update, and delete resource objects containing various attributes in the service layer. Entities shall be able to discover resources. In addition to these the System shall have the following features:

- Authentication and Registration (Identity Management)
- Establish communications session (Add/Delete/Modify)
- QoS/SLA for communication session
- Billing, Charging, and Rating rules
- Group Management
- Security Management (Data confidentiality, integrity, abuse prevention, privacy)

- Framework to establish and incorporate in the session orchestration,
- Data aggregation and storage,
- Policies involving the network provider and the application provider. Examples include incorporating a location tag or time stamp on all data, policy restricting sessions only to certain hours of the day.

Content push/pull Services

Provide API for applications to perform unicast and multicast data push to specified devices within the specified time window. Push may be result of a notification that is triggered as a result of modification of a resource. Provide API for applications to pull data from one or more devices within the specified time window or specified periodicity or other policies that have been established.

Store and Forward Messaging

Applications may request messages to be sent to one or more devices that may not be registered with the network at that time. In this case the communications management entity shall store and aggregate the messages and forward them to the devices at a later time when the devices wake up.

1. Protocol Translation

Translate protocols between application and device as needed. For example, applications may use HTTP while devices may use Constrained Application Protocol (CoAP) or ZigBee protocol.

2. Subscribe/Notification

Application and devices should be able to subscribe to receive notifications upon certain events or when certain resources are updated. Events may be specified as rules on certain resource data.

3. Location and Geo Fencing

Provide device and network based location and location related services such as creating a geo-fence or identifying a group of devices within a region or adding a location tag to the device data.

4. Groups Management

Framework for creation of groups by specifying the members of the group through one of the identifiers of the device, adding additional members or removing members; setting group attributes.

5. Device Triggering

Provide the capability to trigger the device to register with the network and an application through a secondary means such as an SMS. Provide information about the status of the device in the network.

6. Access Control

Control the access to the data collected from the devices based on access restrictions specified by applications in terms which users or devices can access what resources.

7. Data Processing and Storage

Provide temporary and permanent storage for data collected from devices. Process queries on data collected. Provide threshold and expression rules setting and execution on the various data collected from the devices. Notifications could be triggered based on the outcome of the

rules testing.

8. Consumption Statistics/records

Process queries regarding the usage of network resources by a device or a group of devices for billing reconciliation.

9. Data/Metadata Management

Data processing and append (location, timestamp)
Data storage/retrieval

10. API Services

- Definition, Authentication/Authorization and Security
- Service to Device (Management, Establish/Teardown Communication Flows)
- Service to Policy/Resource Management (Rx Extensions for Group Management)
- Service to Data/Metadata Management (Storage/Retrieval)
- Service to Applications (Management, Communications Flows)

11. Security

1. The System shall incorporate protection against threats to its availability such as Denial of Service attacks.
2. The System shall be able to ensure the Confidentiality of data.
3. The System shall be able to ensure the Integrity of data.
4. When some of the components of an M2M Solution are not available (e.g. WAN connection lost), The System shall be able to support the Confidentiality and the Integrity of data between authorized components of the M2M Solution that are available.
5. The System shall support countermeasures against unauthorized access to M2M Services and M2M Application Services.
6. The System shall be able to support Mutual Authentication for interaction with Underlying Networks, M2M Services and M2M Application Services.
7. The System shall be able to support mechanisms for protection against misuse, cloning, substitution or theft of security credentials.
8. The System shall protect the use of the identity of an M2M Stakeholder within The System against discovery and misuse by other stakeholders.
9. The System shall be able to support countermeasures against Impersonation attacks and replay attacks.
10. The System shall be able to provide the mechanism for integrity checking on boot, periodically on run-time, and on software upgrades for software/hardware/firmware component(s) on M2M Device(s).
11. The System shall be able to provide configuration data to an authenticated and authorized M2M Application in the M2M Gateway/Device.
12. The System shall be able to support mechanisms to provide M2M Service Subscriber identity to authorized and authenticated M2M Applications when The System has the M2M Service Subscriber's consent.
13. The System shall be able to support non-repudiation within the M2M service layer and in its authorized interactions with the network and application layers.
14. The System shall be able to mitigate threats
15. The System shall enable an M2M Stakeholder to use a resource or service and be accountable for that use without exposing its identity to other stakeholders.
16. The System shall be able to use service-level Credentials present inside the

M2M Device for establishing the M2M Services and M2M Applications level security.

17. The System shall enable legitimate M2M Service Providers to provision their own Credentials into the M2M Devices/Gateways.
18. The System shall be able to remotely and securely provision M2M security Credentials in M2M Devices and/or M2M Gateways.
19. The System shall enable M2M Application Service Providers to authorize interactions involving their M2M Applications on supporting entities (e.g. Devices/ Gateways/ Service infrastructure).
20. Where a Hardware Security Module (HSM) is supported, The System shall be able to rely on the HSM to provide local security.
21. The System shall enable M2M Applications to use different and segregated security environments.
22. The System shall be able to prevent unauthorized M2M Stakeholders from identifying and/or observing the actions of other M2M Stakeholders in the System, e.g. access to resources and services (see note 1).
23. The System shall be able to provide mechanism for the protection of Confidentiality of the geographical location information (see note 2).
24. The M2M System shall support grouping of M2M Applications that have the same access control rights towards one specific resources, together so that access control validation can be performed by validating if the M2M Application is a member of certain group.
25. The System shall enable security protocol end-points to protect portions of individual application-generated data so that intermediate entities (whether trusted or untrusted) forwarding the data are unable to access the protected portions of the data in clear text.
26. The System shall enable security protocol end-points to protect portions of individual application-generated data so that security protocol end-points can detect modification, including modification by intermediate service layer entities (whether trusted or untrusted) forwarding the data.
27. The System shall enable security protocol end-points to protect portions of individual messages so that intermediate entities (whether trusted or untrusted) forwarding the messages are unable to access the protected portions of the messages in clear text.
28. The System shall enable security protocol end-points to protect portions of individual messages so that security protocol end-points can detect modification, including modification by intermediate service layer entities (whether trusted or untrusted) forwarding the messages.
29. The System shall enable security protocol end-points to establish security sessions, which are used for protecting portions of one or more messages so that intermediate entities (whether trusted or untrusted) forwarding the messages are unable to access the protected portions of the messages in clear text.
30. The System shall enable security protocol end-points to establish security sessions which are used for protecting portions of one or more messages so that security protocol end-points can detect modification, including modification by intermediate service layer entities (whether trusted or untrusted) forwarding the messages.
31. The System shall enable security protocol end-points to protect portions of messages or data so that intermediate entities (whether trusted or untrusted) forwarding the messages or data are unable to access the protected portions of messages or data in clear text.

32. The System shall enable security protocol end-points to protect portions of messages or data so that security protocol end-points can detect modification, including modification by intermediate service layer entities (whether trusted or untrusted) forwarding the messages or data.
33. The System shall enable security protocol end-points to authenticate each other without relying on intermediate service layer entities (whether trusted or untrusted).
34. The System shall be able to support distributed authorization functions for making access control decisions, providing Access Control Policies and providing authorization attributes (e.g. roles).
35. The System shall be able to expose an interoperable interface to provide Access Control Policies by means of specified access control policy language.
36. The System shall enable individuals to establish policies for controlling access to their personal identifiable information even when it may have been collected without their knowledge.
37. When the M2M Devices are grouped and the M2M Gateway is authorized as delegate of the group for accessing the M2M Server, the M2M Gateway shall be able to, on behalf of the M2M Devices in the group, perform Mutual Authentication with the M2M Server.
38. When the M2M Devices are grouped and the M2M Gateway belongs to a third party, System shall be able to protect Security and Privacy of communication between individual M2M Device and M2M Server from other M2M devices and the third party M2M Gateway.
39. A secured API shall enable application and service layer entities to make use of sensitive functions and data residing within the Secure Environment, independently of the technical implementation of the Secure Environment.
40. The System shall enable authorizing a entity to temporarily delegate its access rights (or a subset thereof) to another authorized entity, wherein the dynamically delegated access rights shall not enable the "delegated-to" entity to delegate the same rights in turn to a third entity.
41. The System shall support classification of application data by M2M Applications into various security levels that are specified by and support the mapping of these levels to applicable security capabilities.
42. The System shall enable to protect portions of individual application generated data that is at-rest (e.g. hosted data) for integrity protection and data creator Authentication.
43. The System shall enable to protect portions of individual application data at-rest (e.g. hosted data) for confidentiality protection.
44. The System shall ensure that the end-to-end data Credentials are protected for Confidentiality, integrity and against tampering.
45. The System shall ensure that the end-to-end data Credentials are protected from exposure to intermediate entities.
46. The System shall enable pre-defined conditions to be protected from unauthorized modification.
47. The System shall enable the deletion of M2M data produced/stored by the M2M Devices/Gateways based on request from an authorized entity.
48. The System shall store and process privacy preferences in an interoperable manner.
49. The System shall support privacy profiles at various levels to care for conditions of legal requirements, manufacturers, and data subjects.
50. For M2M Application Service data, that are processed by an M2M

Application Y in a M2M entity (e.g. M2M Gateway) on its path from an originator X to the recipient M2M Application C, The System shall provide means that enable the recipient to verify both:
Integrity of the data received by the M2M Application Y from the originator X; and, at the same time: that the M2M Application Y that has processed the data has not been compromised.

51. The System shall be able to prioritize privacy profiles where there is a conflict between profiles (legal profile takes priority over data subject profile, for example).
52. The System shall be able to support configuration of security related settings of its infrastructure side components by a privileged user through standardized API.
53. The System shall allow overriding of security settings by a privileged User through standardized API.
54. The System shall support a mechanism enabling addition/deletion of information enabling authentication of entities through standardized API.
55. The System shall enable delegation of security functions (e.g. message authentication/integrity protection) of an entity to a trust-worthy entity.
56. The System shall protect the authenticity, Integrity, and Confidentiality of the representation of the delegated access rights.
57. The System shall be able to revoke the representation of the delegated access rights.
58. The System shall be able to verify the App-ID to support the detection of impersonation or to support revocation.
59. The System shall be able to reuse the privacy policy of the underlying network.
60. The System shall be able to share its privacy policy with the underlying network.
61. The M2M Devices shall provide a mechanism to prevent installation or modification of the software/middleware/firmware, which run on the Devices unless an allowed stakeholder authorizes it.
62. The System shall be able to detect installation or modification of the software/middleware/firmware of M2M Devices that has not been authorized by an allowed stakeholder.
63. The System shall enable allowed stakeholders to restrict or prevent operation of M2M devices using software/middleware/firmware that the stakeholders did not authorize.
64. The System shall be able to prevent malfunction of M2M Devices caused by receiving unsolicited messages or information.

The above mentioned common functions shall be the integral components for a "Common M2M Service Layer" capability such that the developers of the Smart City Applications or for that matter any M2M/IoT application would not require to develop these capabilities in the business application.

Conclusion:

The above mentioned common functions shall be the integral components for a "Common M2M Service Layer" capability such that the developers of the Smart City Applications or for that matter any M2M/IoT application would not require developing these capabilities in the business application.

As has been emphasized above that in order to have a robust, interoperable M2M/IoT ecosystem, it is necessary to have a standards compliant Common Service Layer which should provide standards compliant open interfaces to the application developers both at the device or field domain (sensor/actuator side) and also to the applications in the infrastructure domain (monitoring and/or analytics applications). Not only would this approach bring the overall cost of such implementations down but would also enable the developers to create new and innovative applications at a much faster pace with far less resources. Additionally, in Smart City Application areas, this would also enable the city authorities managing the resources to run analytics on top of the common service layer and get detailed projections about the key elements, which help them plan in an informed way. It would also make it possible for the law enforcement agencies to be able to monitor or trace the communications in order to have effective law enforcement and nab the wrong doers. From the security standpoint only this approach can make it possible to have a seamless implementation of security and privacy while permitting sharing of data across divergent applications.

Once, such a framework is accepted as the standard for the smart city, the same would bring in the desired interoperability and data sharing into the smart city ecosystem.

A closer look at the available standards for such an approach shows that oneM2M is the most comprehensive standard which fulfills most of the requirements mentioned above. As oneM2M specifications are created as an outcome of combined efforts by the eight global SDOs (See Annexure A) with active involvement by the key industry players, the specifications have turned out to be extremely robust and practical.

For the Smart City ICT infrastructure, it is therefore recommended to map the aforementioned requirements of the Common Service Layer against all the standards and or framework available in this domain to identify the most suitable Framework/standard, which fulfills all the necessary requirements as mentioned in the sections above.

NEXT STEPS:

1. Review of ALL the candidate Global standards for the Common Service Layer.

2. Recommend the **India appropriate** Architecture and Standard for adoption in the Smart Cities in India.

Study - PART 2 – Section 3

Task Group Report

on

Technical Requirements Analysis

of

ICT Reference Architecture

for

Smart Cities/Infrastructure

Smart City System Architecture

The Smart Transformation

The society, the business, the infrastructure, the services and all other aspects of the civilization on the planet Earth are going through a paradigm shift in the wake of technological advancements, especially in the field of ICT.

All the ecosystems, be it Smart Cities, Smart Grid, Smart Buildings or Smart Factories now find themselves making three classes of transformations:

- ⇨ Improvement of infrastructure – to make it resilient & sustainable…
- ⇨ Addition of the digital layer- which is the essence of the *smart paradigm*; and
- ⇨ Business process transformation - necessary to capitalize on the investments in smart technology.

Drivers for the "Smart" Paradigm:

In general, the objectives expected from the Smart Paradigm in any context and therefore the implementations of ICT in Smart xxx are:

- ⇨ **Optimization**: Looking at all data coming in from various input sources – resources, utilities, devices and services and putting in systems such that they can improve their operations and make it more efficient.
- ⇨ **Predictive failure information**: Forecasting the probability or knowing when a system or machinery will go down. And as next steps, taking measure to address that.
- ⇨ **Improved usage information:** Understand how users are using different services and the consumption of essentials. Enhance what is falling short, and de-emphasize what is excess.
- ⇨ **Improved failure and diagnostic information:** Make sure services are operating and generating revenue.
- ⇨ **Transparency:** Facilitated by making the information, processes, costs, consequences, more open and democratic
- ⇨ **New services packages:** With more information about user behavior and services consumption patterns, the solution Deployers will be able to offer more tailored services in future.

The Interplay – Smart infrastructure – Smart Cities

The relationship between Smart Infrastructure and Smart Cities needs to be understood in this context: "In a smart city, energy, water, transportation, public health and safety, and other key services are managed in concert to support smooth operation of critical infrastructure while providing for a clean, economic and safe environment in which to live, work and play".

Hence, the perspective in Infrastructure Design for any city has undergone a paradigm shift with advent of convergence and networking technologies, solutions for information, communication, entertainment, security and surveillance; which are beginning to have a profound impact on the way we look at the Buildings' Design (be it residential or commercial) and Town Planning.

Cities are intricate composite environments and the manner in which cities are operated, financed, regulated and planned are extremely complex to say the least. City operations are

multidimensional and comprise of multiple stakeholders whose dependencies and interdependencies affect and ultimately determine the built environment.

The various departments mostly overlook these dependencies and interdependencies though known, in their efforts and focus of providing their services and of being answerable only for the services they provide. Part of the answer to making cities 'smarter' is a more all-embracing coordinated management of resources and infrastructure, a collaborative approach to a cleaner greener environment, and harmonized governance that result in a better quality of living of its citizens.

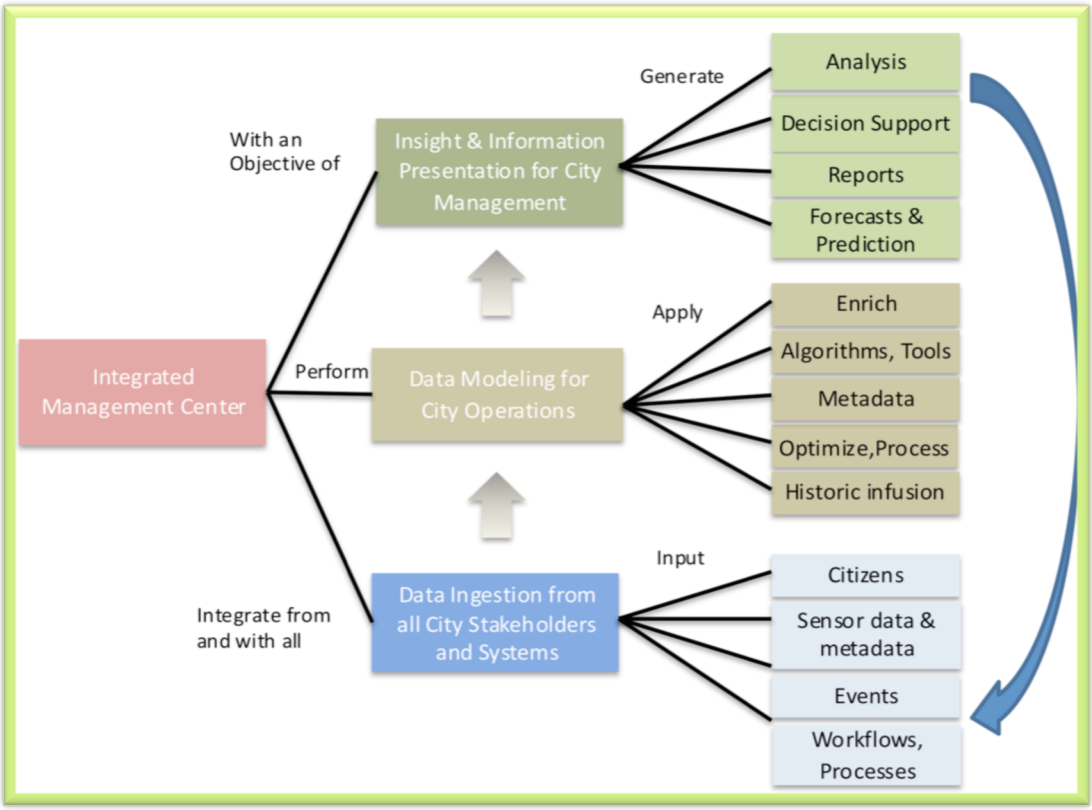
It is true however, that convergence is still eluding the evolved citizens of today's global village because of a lack of harmonized standards in the respective ecosystems of the Smart Homes, Smart Buildings and Smart Cities. The smart nodes of one network cannot talk to smart nodes of the other networks. A wide array of proprietary systems/solutions, or systems/solutions with very limited interoperability are being deployed in each application areas for the today's home automation, building automation, industrial automation or even the infrastructure automation needs of the society. This is definitely going to ensure that we shall not be able to derive the maximum benefits of these Technologies, whatsoever.

The hugely complex nature of a smart infrastructure project creates a very real risk that oversights in the planning phase can cause the sub-optimization of sub-systems, which can severely impair the overall success of the project. Organizations can mitigate this risk by taking a far-reaching, structured, and detailed approach to project planning. By encapsulating the requirements of all stakeholders (both within and outside an organization), modeling the impacts of change, and tracing requirements throughout the project, it is possible to quantify the impact of different decisions in the planning stages, rather than realize mistakes once the project has been completed.

Looking at how the market is at an inflection point between talking about what 'smart city' means and understanding how to implement it, the evidence of the shift is in the increasing maturity of the demand side, implementing an Integrated Infrastructure to enable collaborative citizen's services with open data and innovative apps and develop standards and protocols for future city development.

A vast body like a city consists of large number of heterogeneous information resources. These include sensors, exchanges between or information from citizens, the various workflows and processes, events that occur, etc. that can together complement the integrated management of smart cities. The relationships of these diverse information resources are complicated and could be complementary, reinforced or redundant relationships. The data gathered can further be processed and modelled, correlated with historic data and other activities performed on it before it can be made insightful and can be presented to offer MIS, analysis, decision support or forecasts.

There is also a recursive cycle to the data in a Smart City. Information that is generated is information that is consumed which in turn adds to the information generated which becomes information used again.



Smart City ICT Architecture: The M2M & IoT Perspective

It is now a well-accepted fact that the Silo'd way of deploying the M2M/IoT infrastructure is leading us nowhere and we definitely need a standardized Unified **Common ICT Backbone Architecture** approach to tackle the problem. In a Smart City scenario, such approach is nothing less than essential, as only this would enable true interoperability between divergent devices as well as applications while maintaining identity and access control. Along with this, the sharing of data with ensured security and privacy becomes a practical feasibility.

The extensive work done by various global SDOs has very comprehensively defined the frameworks & roadmap for future ICT Infrastructure. However, the new paradigm of "Internet of Things" has given rise to a new aspect of the way human, machines and things are going to communicate with each other in the very near future.

Internet of Things is all about "heterogeneous" and "aware" devices interacting to simplify people's life in some way or the other. The Heterogeneity of the IoT paradigm has made it imperative to have a fresh look at the prevalent architectures & frameworks of the ICT Infrastructure being deployed or being developed.

The IoT value chain is perhaps the most diverse and complicated value chain of any industry or consortium that exists in the world. In fact, the gold rush to IoT is so pervasive that if you combine much of the value chain of most industry trade associations, standards bodies, the ecosystem partners of trade associations and standards bodies, and then add in the different technology providers feeding those industries, you get close to understanding the scope of the task. **In this absolutely heterogeneous scenario, coming up with common harmonized standards is a major hurdle.**

Hence, true convergence is still eluding the evolved citizens of Today's Super industrial Society, because of lack of harmonized standards in the respective ecosystems of Smart Homes, Smart Buildings, Smart Grid and Smart Cities. The smart nodes of one network cannot talk to smart nodes of the other networks. Multitude of 'proprietary systems/solutions', or 'systems/solutions with very limited interoperability' are being deployed in each application areas for today's Home Automation, Building Automation, Industrial Automation or even the Infrastructure Automation needs of the society. This is definitely going to ensure that we shall not be able to derive the maximum benefits of these Technologies, whatsoever…

End-to-End Interoperability:

There is an irrevocable global consensus on Interoperability & Data Sharing amongst all the Utilities, Infrastructures and Services in any city to improve the operational efficiency and bring comprehensive & smooth co-ordination among all the city stakeholders.

Discussions and deliberations amongst all city Planners, Administrators, Technology Providers and SDOs conclude with merits of an End-to-End Common Infrastructure; yet, the ground reality is very different. The essential approach being followed by one and all is to create a Smart City Software Platform on top of all the individual utilities' Legacy infrastructures to capture their respective diverse and heterogeneous data; and develop Common Data & Information Models at the Application Layer to bring the required uniformity, user friendliness & interoperability for efficient and smooth operation & maintenance of infrastructure and citizen services. Even this approach varies from city to city and with each solution/technology provider. Hence none of these City Platforms or Interoperability Solutions/Technologies is replicable. This tends to create Vendor Lock-in and heterogeneity in spite of similar requirements of most of the cities.

India's Unique Opportunity:

India, since its independence 75 years ago, has been continuously striving to develop a robust & resilient Infrastructure to bootstrap the economic growth and empower its citizens with a sustainable quality of living conditions. Yet, somehow, till date, our critical infrastructure like, Energy, Water, Transportation, Waste Management, Health etc. are neither reliable nor smart n resilient.

However, in this situation of inadequate infrastructure, India has a unique opportunity to leapfrog in designing its Critical Infrastructure to be most optimized, smart, sustainable, secure and resilient with minimum Life Cycle Cost. This is because we do not have any legacy smart infrastructure developed and deployed in Silo'd fashion, as in the developed nations.

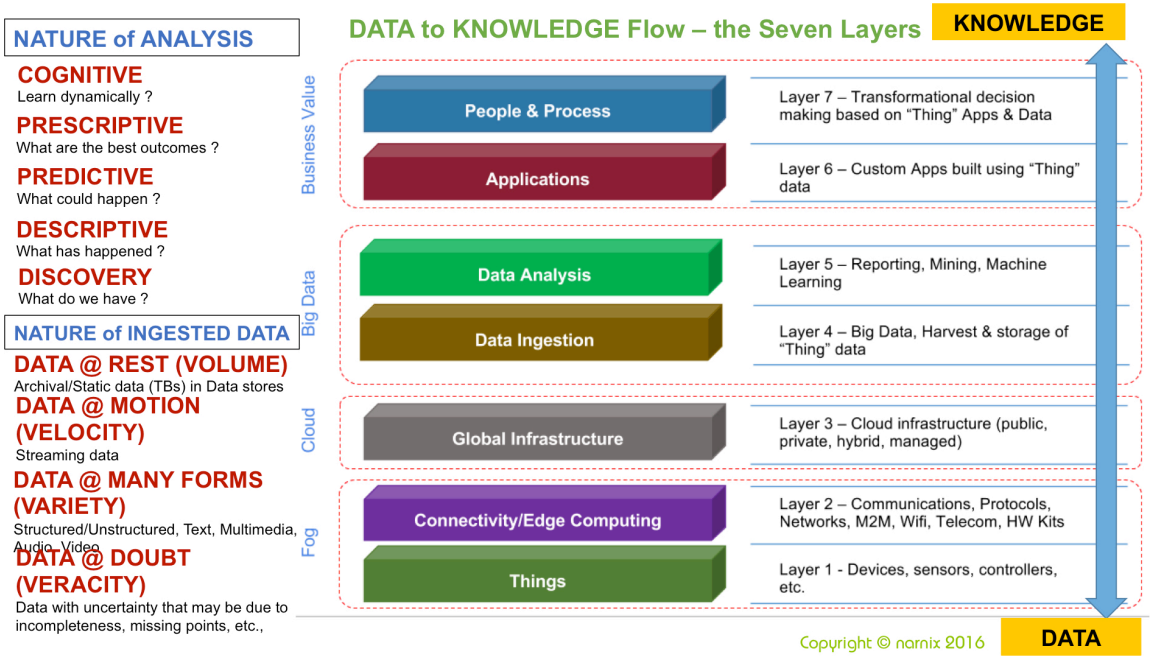
This, along with bringing down the TCO and the Carbon Footprint of the Smart Infrastructure, shall also bring unparalleled and seamless End-to-End Interoperability and Operational Efficiency. Further the solutions deployed shall be vendor agnostic, and replicable from city to city helping the vendors, as well as, the cities and its citizen.

Two Underlying philosophies

1. **Standards are the chromosomes of Smart Infrastructure**

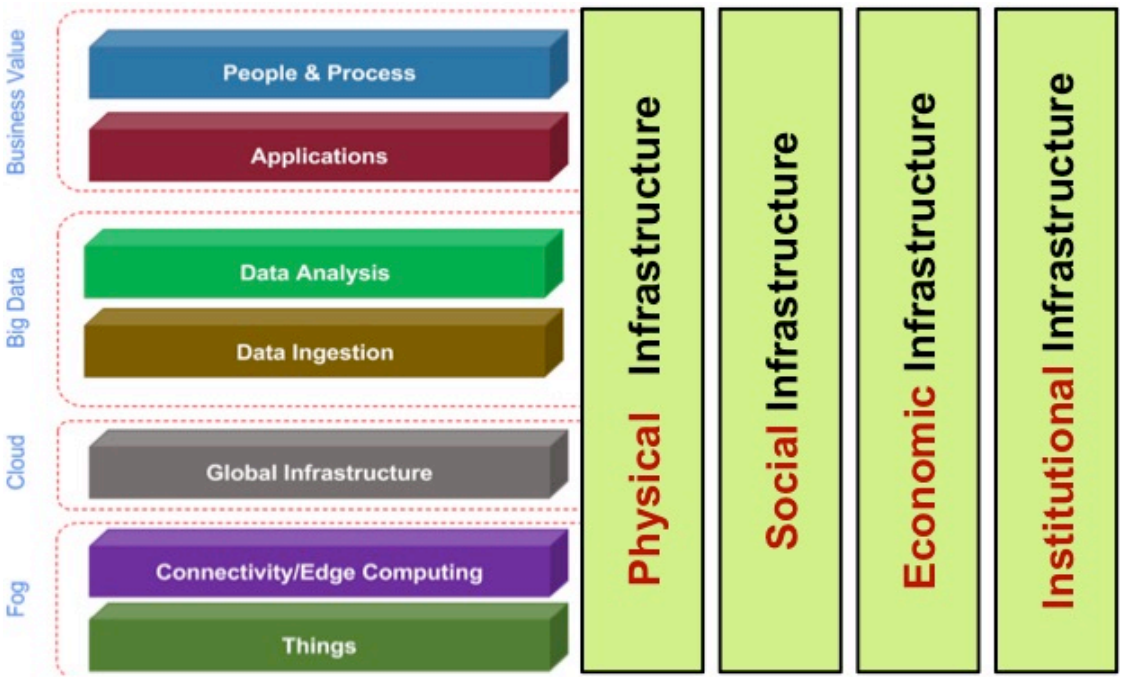
2. If **"Data is the Oil of the 21st Century"** (without pollution side effects), then **"Big Data" is the Crude Oil,** as it needs lot of processing before it becomes usable.

Seven Layers of Information Flow – from Data to Knowledge

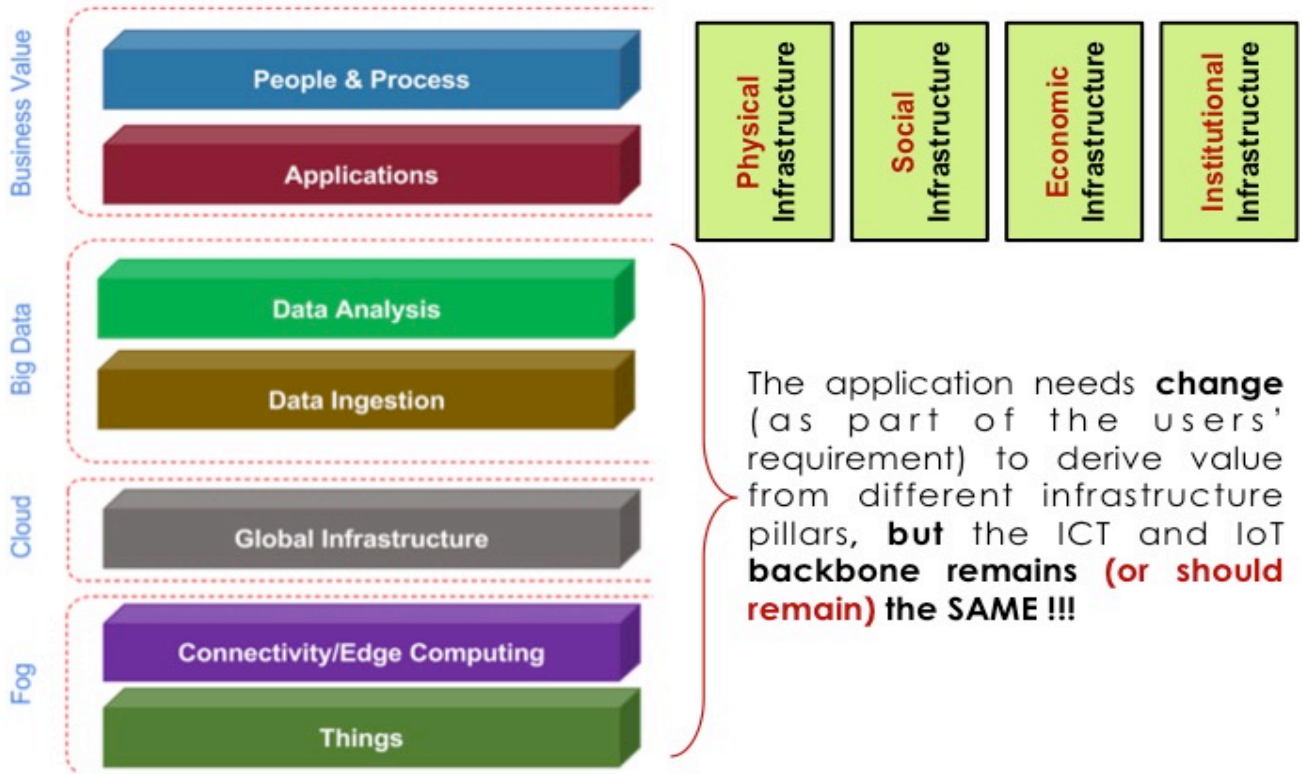


Mapping the Smart Infrastructure Philosophy to High-level Functionality

To analyze the relevance of Big Data & Information management in the Smart Cities, we need to contextualize this "Seven Layer Information Flow & Processing" with the entire gamut of use cases to convert the diverse and heterogeneous data collected in a city to knowledge that would in turn be further processed to provide the Actionable Insights to the Smart City Managers, Planners and other stakeholders. This is achieved by mapping the "Seven layers" to the Four Pillars of Smart city framework – Physical Infrastructure, Social Infrastructure, Economic Infrastructure and the Institutional Infrastructure.



The detailed analysis shows that different city applications need changes as part of the user requirements to derive value from different infrastructure pillars but the ICT (and IoT) backbone remains the same.



City needs Enterprise Architecture

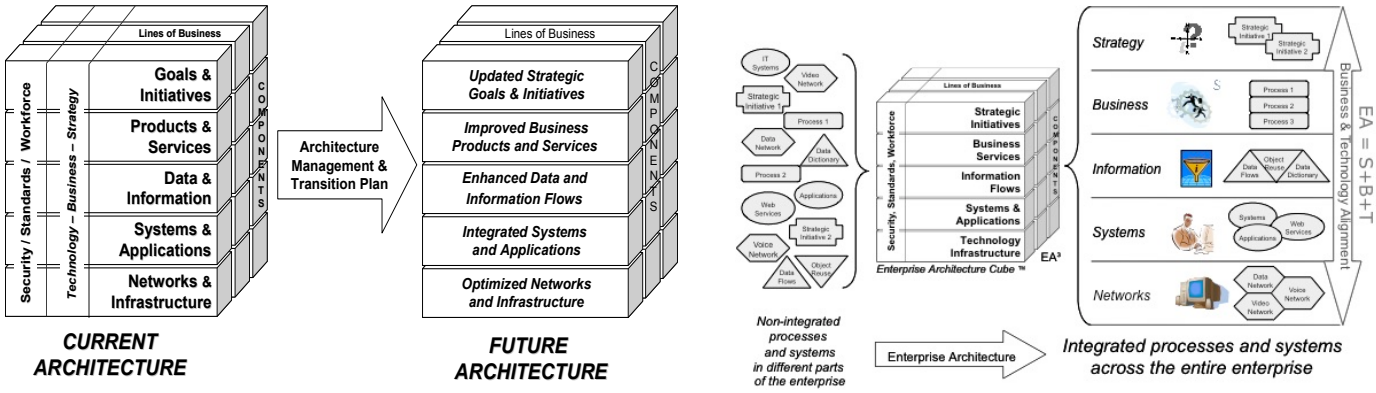
Any complex system e.g. a building needs to be carefully designed, using a systematic approach, to describe in detail its structure, all the processes needed to fulfill the purposes of the building and all the subsystems within it (water, waste, electricity, telecoms, etc.) and how its design meets the different functional requirements of its users. For instance, for an airport there needs to be detailed descriptions of how luggage is moved around, how passengers get to their plane, how fuel is provided, how planes are serviced, how security is managed, etc., as part of the overall architecture of the building complex.

This is needed at the construction phase to ensure that the building is properly designed to enable it to fulfill all the requirements of its purpose. However, it is also needed to support the on-going management of that building and to support the design of any alterations and upgrades needed to meet any change in requirements or to benefit from new technologies to fulfill existing requirements.

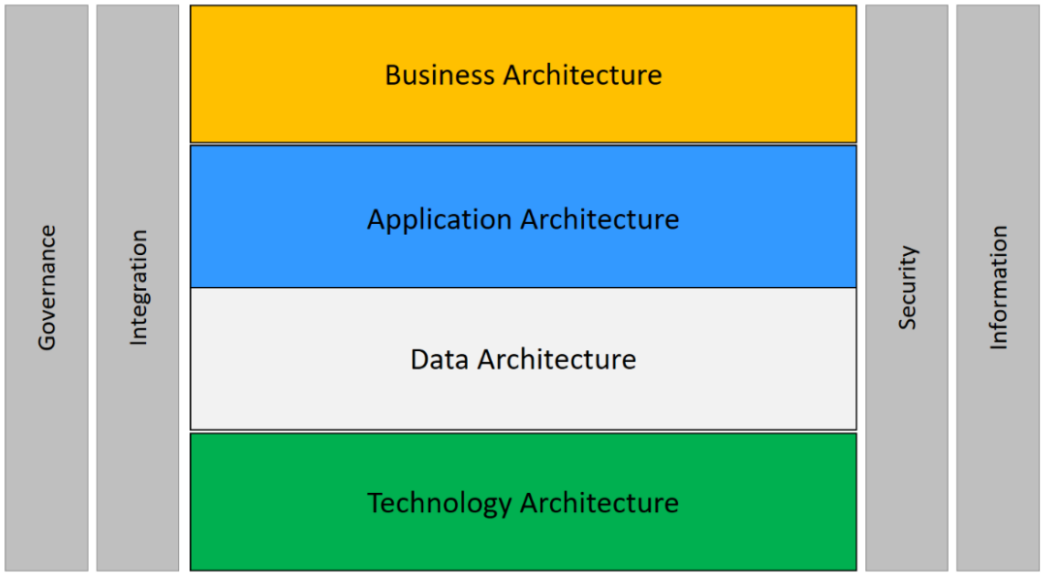
The aims and strategy, business structures and business processes of an enterprise and the software applications and communications infrastructures that support them, also need to be carefully described and reviewed. Only in this way is it possible to ensure that its business structures and processes can effectively support the delivery of its strategies and outcomes and to allow these to change and adjust to changing requirements and opportunities.

Enterprise Architecture is the definition and description of an enterprise from the combined viewpoints of its strategy, business structure, business processes, information systems and

technology, both in terms of how it is at present, and of how it needs to be in the future.



Enterprise Architecture: The analysis and documentation of an enterprise in its current and future states from a Strategy, Business, and Technology perspective. ***EA = S + B + T***

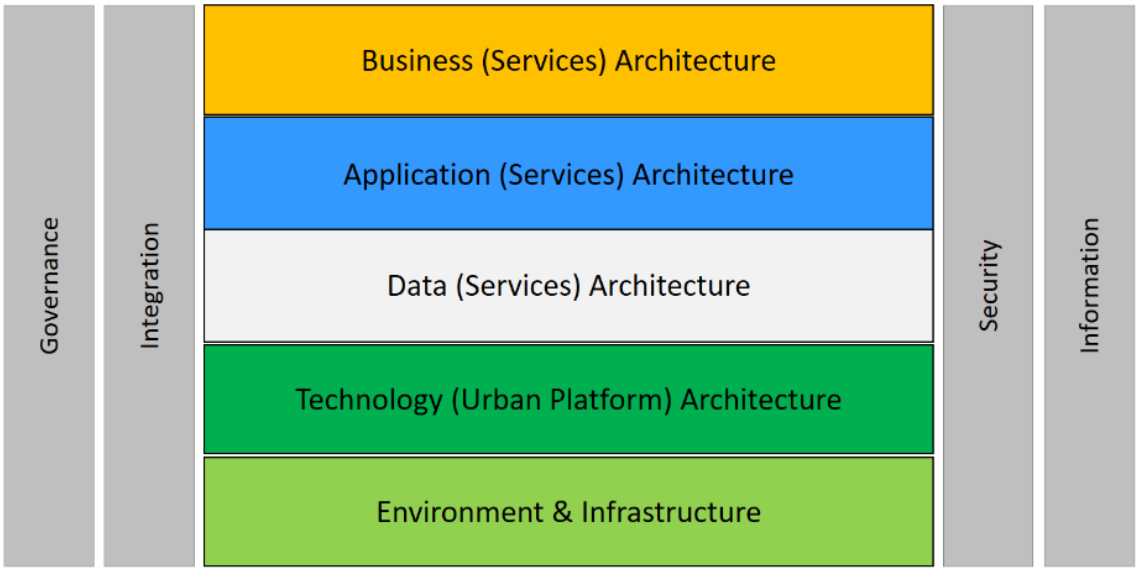


Translating City Needs to Enterprise Architecture: The Philosophy

Cities need a structured way to describe how the city works, to determine:

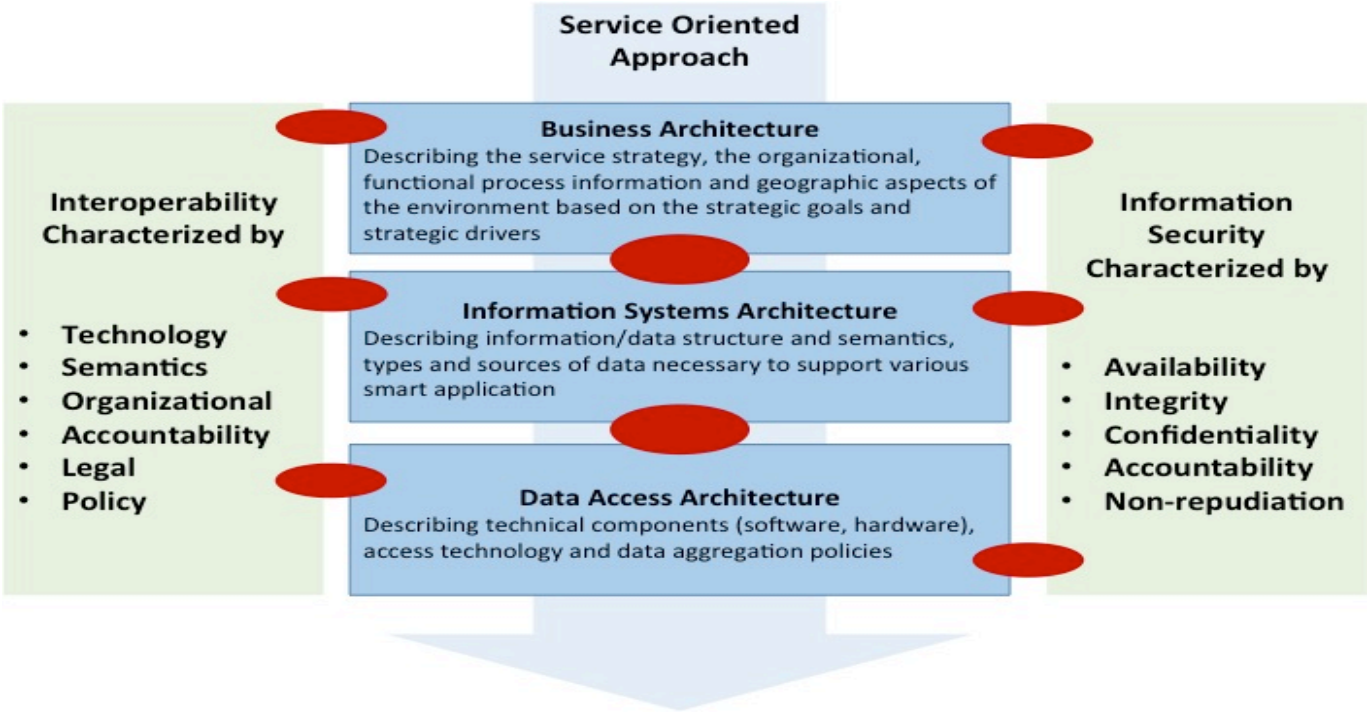
- ⇨ How effective are the organizational structures and the business processes in the city at enabling the city strategy to be delivered
- ⇨ How well the software applications and the technology infrastructure behind them support the business processes
- ⇨ How appropriate is the built environment and infrastructure networks of the city to support the delivery of its strategy
- ⇨ Etc. … And what changes might be needed.

Developing an Enterprise Architectural Framework and a Key Definitions Framework for smart cities would need to draw on existing standards describing the way cities work in order to ensure that the processes deal with all of the key issues. Clearly adaptations would be needed - for instance we might add an Environment and Infrastructure layer:



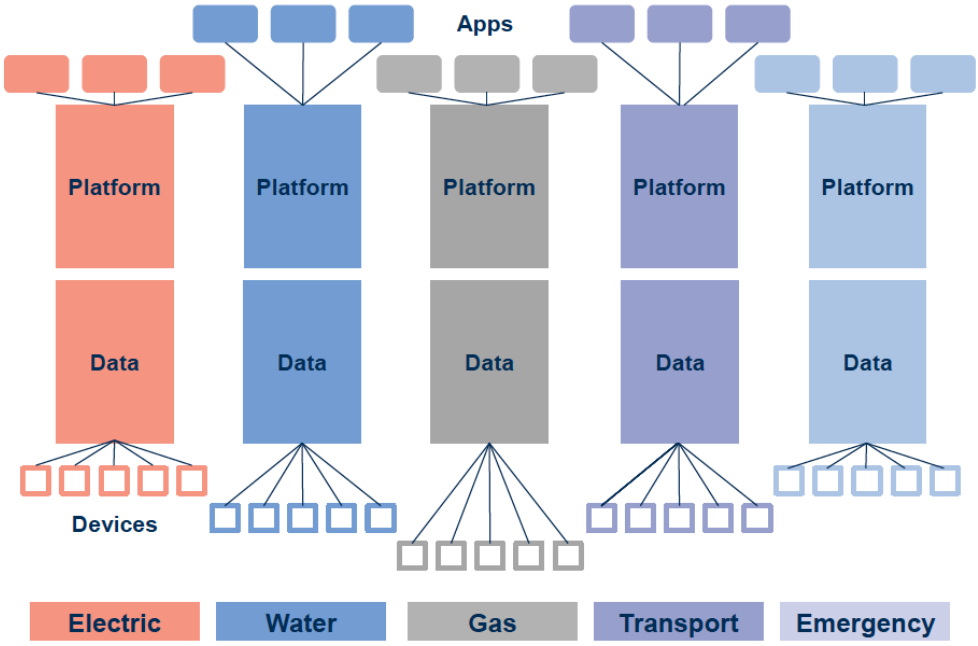
Translating the Smart Infrastructure Architecture Schema to Technology Layers

EA defines how business and Information systems alignment should be achieved. It is where business capability (financial and market goals) and technology capability (products, vendors, and functionality) are tied together with organizational capability (people or process) to drive an ongoing strategy or desired outcome. SOA is recognized as a methodology optimized in applications architecture or Service architecture, with a view to deliver one of the domains within EA namely the applications architecture.

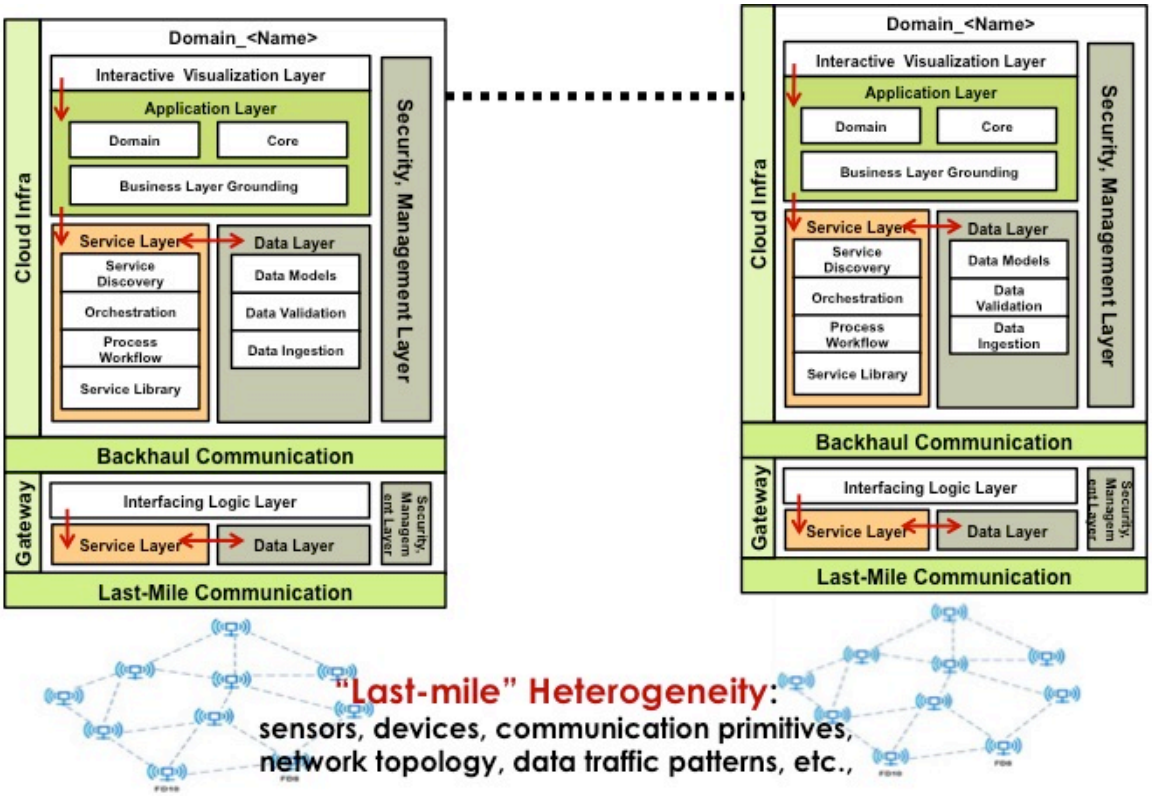


Functional Architecture: The Existing Silo'd Manner of Operation

A review of ICT Infrastructures of utilities currently in Practice Globally shows the Silo'd architecture as shown below:

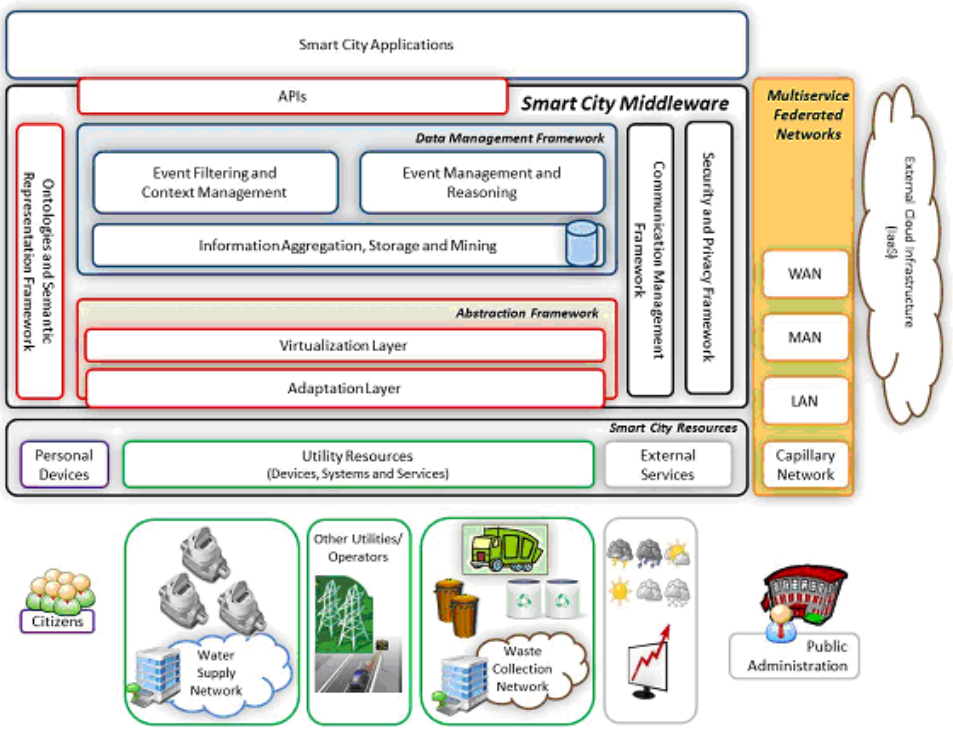


And the Granular analysis of the ICT Architectures of the deployments shows the overall architecture as illustrated below:

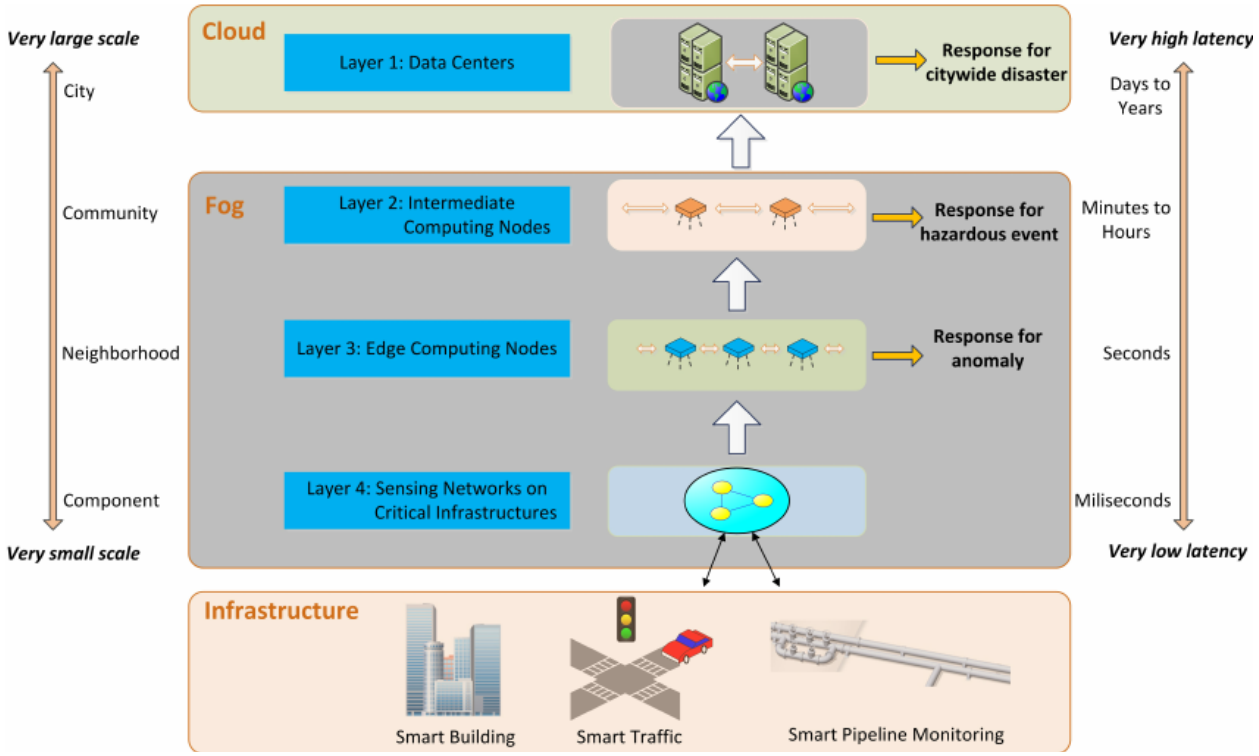


Typical Individual Utility ICT Architecture

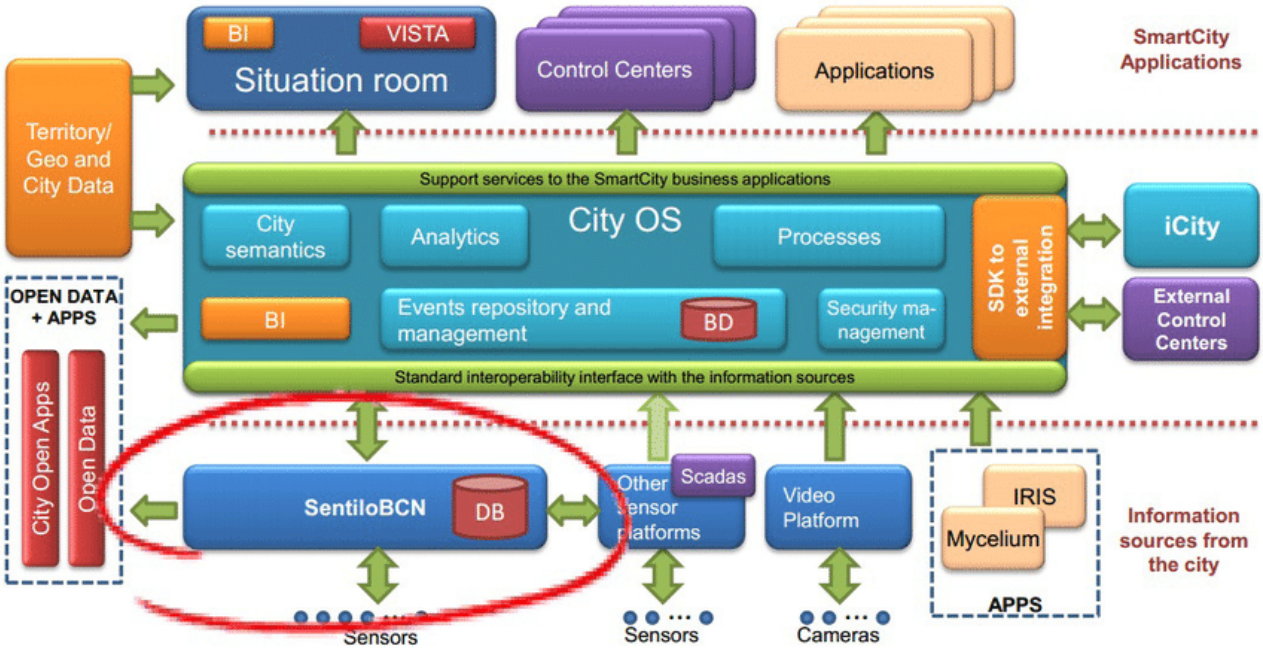
A few examples of contemporary ICT Architectures in Vogue



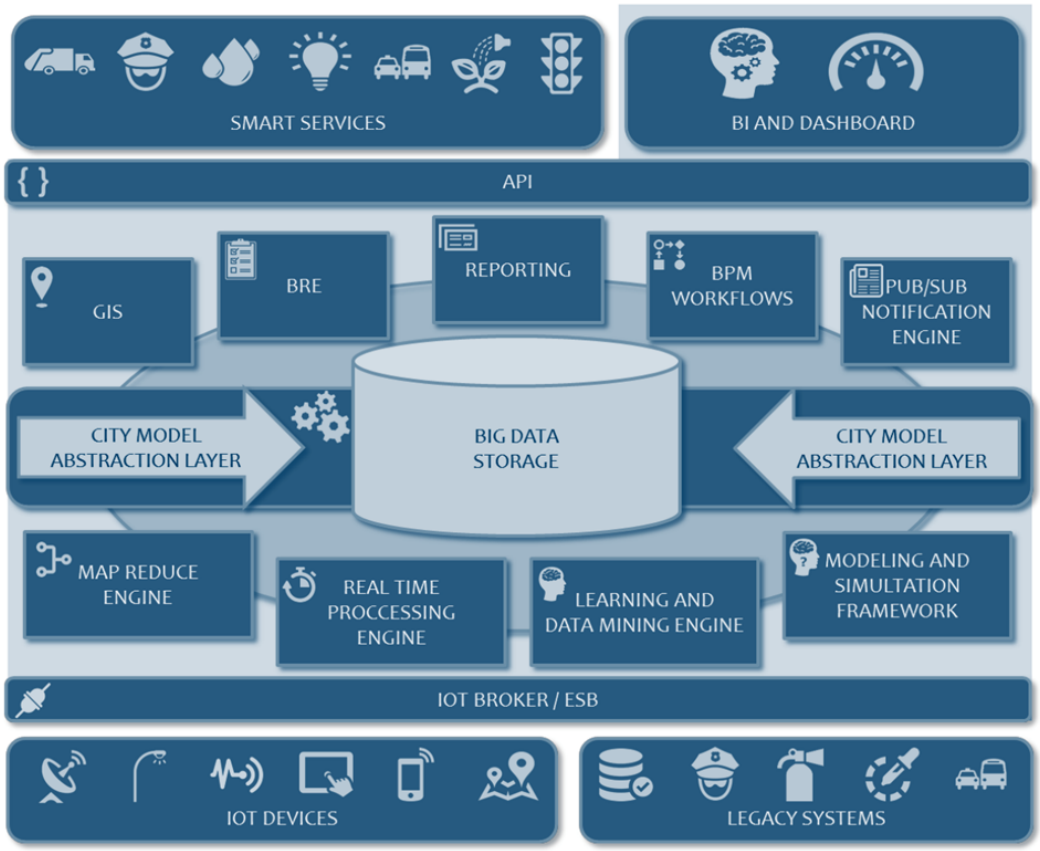
Fog Computing (4 Layer) Architecture for Smart Cities



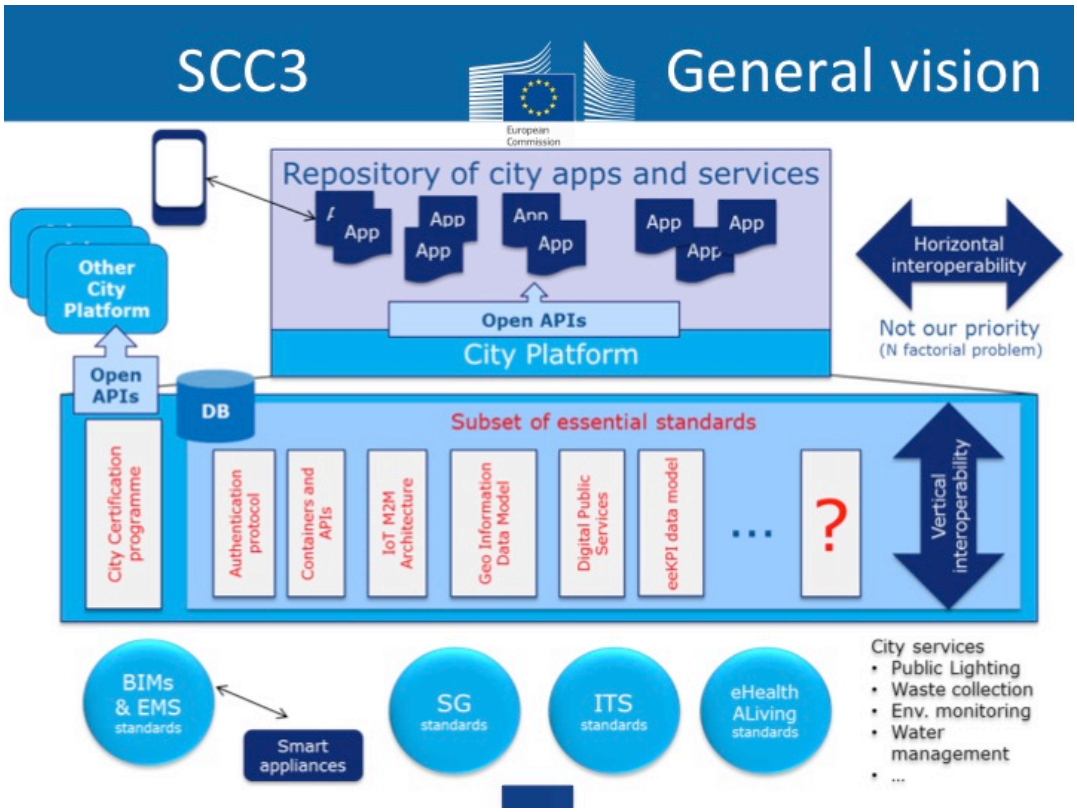
Barcelona Smart City IT Architecture



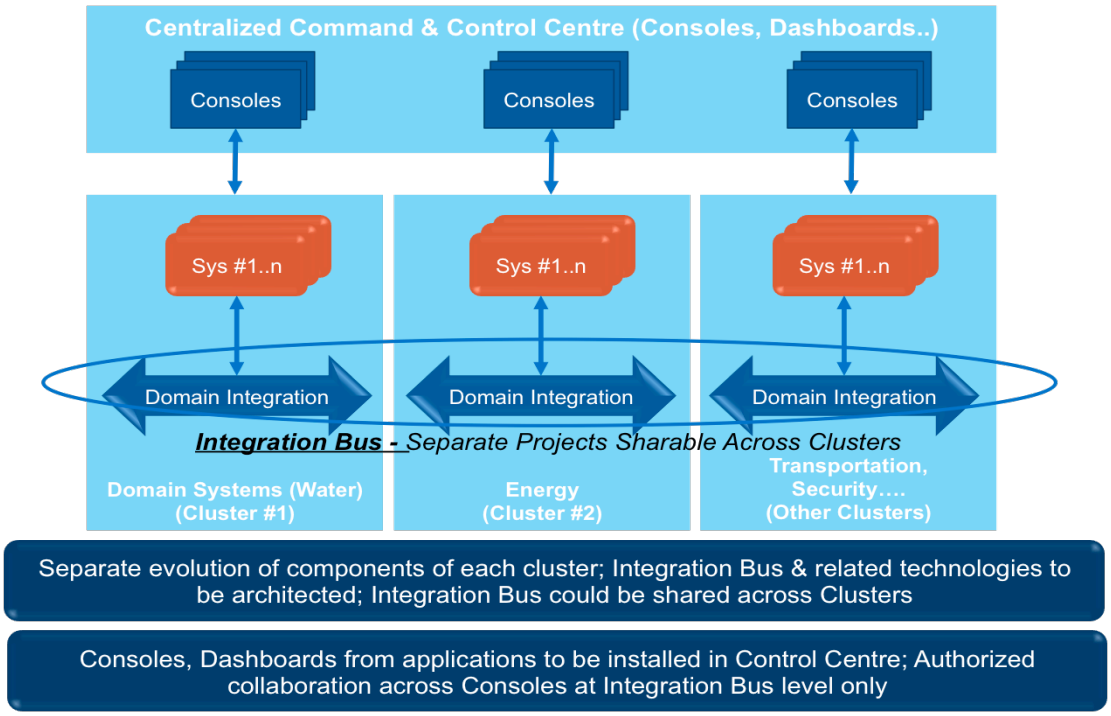
Greenwich Architecture View



Smart Cities ICT Architecture Evolution

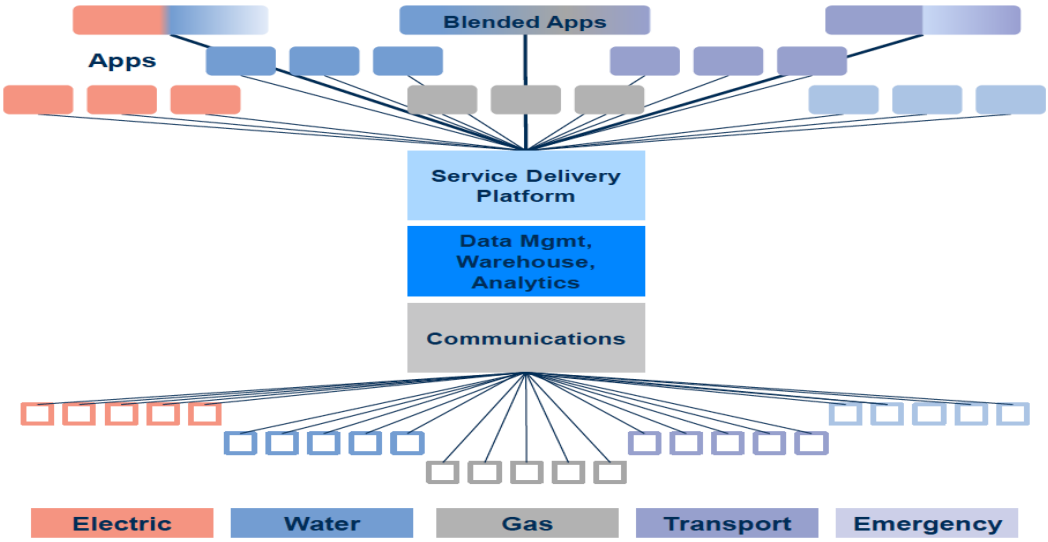


It can be observed from the review of all these initiatives that the underlying common philosophy is to integrate different Silo'd Infrastructures & Services Domains to provide a unified view of the Smart City operations. However, the Horizontal Integration evolves differently in each city depending on its current status of Silo'd Domains & Infrastructures.



The Paradigm Shift: From Silo'd to Unified - From Vertical to Horizontal

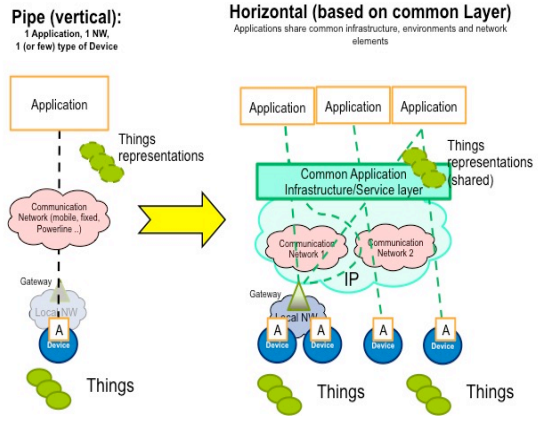
All sectors in the infrastructure framework are influenced by the unified ICT backbone paradigm. However, a common infrastructure pool enables the creation of a interconnected and truly homogenous system with seamless communication between Services. Coordination, collaboration and harmonization can be better implemented by the effective use of standards based open, common and shareable, information and communication technologies. The disconnect amongst technological trends being pursued by the stakeholders of the now homogenous smart infrastructure needs to be bridged without any further delay to maintain the Lifecycle Cost / TCO (total cost of ownership) of these individual components within viable economic thresholds.



A converged common ICT Infrastructure Pool

Cities that are serious about getting smart know that they cannot rely on traditional ways of doing things. Vertical rollouts, where each IoT use case is propped up by a dedicated network, use case-specific data exchange mechanisms, and single-use devices, do not scale.

As city planners strive for greater cross-departmental synergies, it is essential that networks and devices, as well as data, can be used for more than one purpose. Even better if various functions, such as device management, security and communication management, can be shared by multiple IoT applications



M2M Evolution : OneM2M Architecture Approach

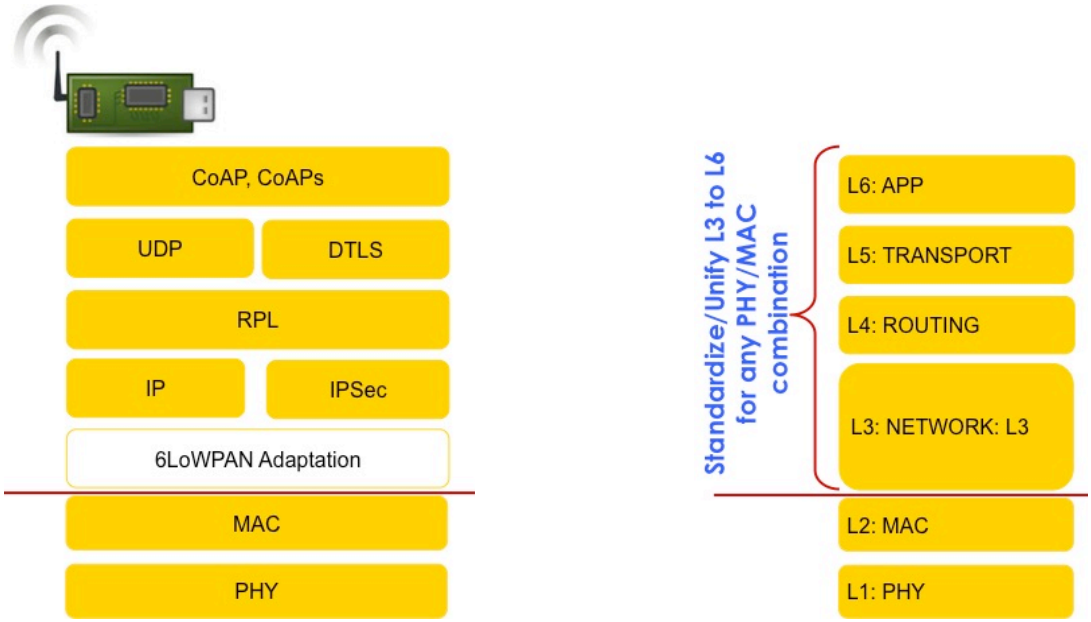
Common Service Layer: Supported functions (CSFs)

Last Mile Communication:

The rapid growth in communication technologies for last more than Four decades has kept the users confused with multiple choices with their respective diversities and USPs for different applications and use cases. As a result, stakeholders of different ecosystems have chosen different Technologies and Protocols to meet their respective applications needs. In some cases even different segmented stakeholders of a common ecosystem have developed/adopted different, communication technologies, protocols, data semantics and standards. This has been dully illustrated thru a few case studies in earlier section.

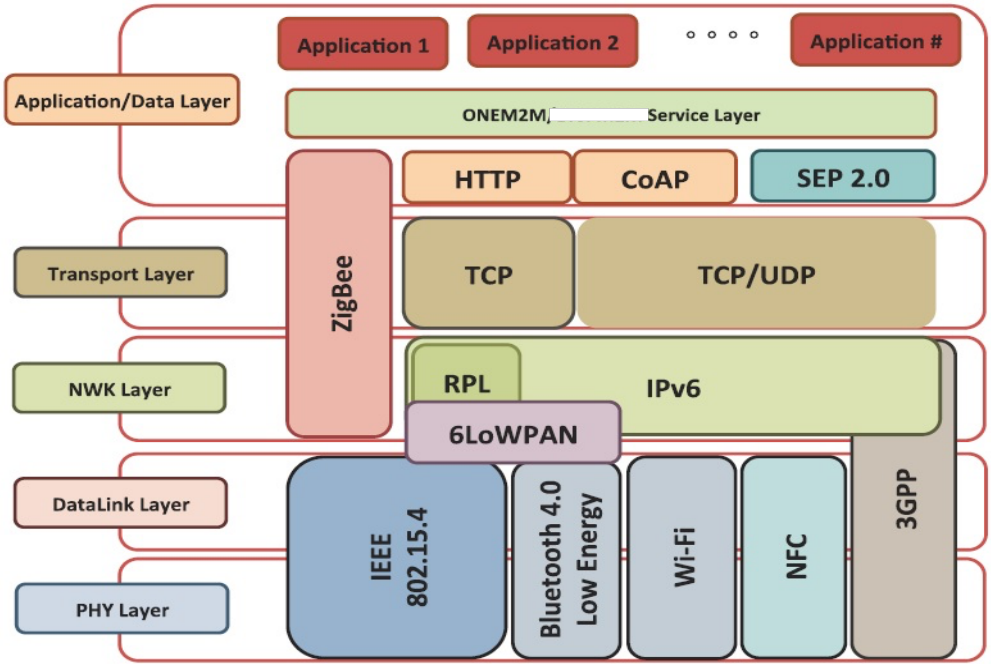
This disconnect is a major roadblock in Unifying the ICT Backbone of any Smart City End-to-End comprehensively. This is keeping the Communication Technology market fragmented and Cost of Communication Infrastructure in Smart Cities very high due to deployment of individual communication networks for each utility, city application & service. Interestingly, NO Global SDO is even attempting to address this area. However, India has identified this as a crucial Gap Area for Standardization and has the following inference after the detailed review and analysis of the problem (a separate Report has been prepared on the subject):

The last mile communication stack comprise of Seven Layers as per the OSI Model. The L1 being the PHY Layer depends on the Communication Technology and its Medium viz.: Wired, Power Line, Wireless and even with-in the respective Domain, the Type of Modulation, Frequency Band and other Physical characteristics of communication. This layer can not be unified because of diverse deployment scenarios shall need different Communication Mediums and other physical characteristics to get the most optimum throughput in communication. The L2 layer is the MAC and it is closely linked and dependent on the L1 – Phy Layer. Hence this layer also cannot be unified. However, it has been inferred from the detailed study and analysis that for a given Umbrella Use Case scenario of Smart Infrastructure, all other Layers i.e. Layer 3 to Layer 7 can be unified including the most fragmented characteristics – Data Semantics.



Sensor Web: Field Device Stack

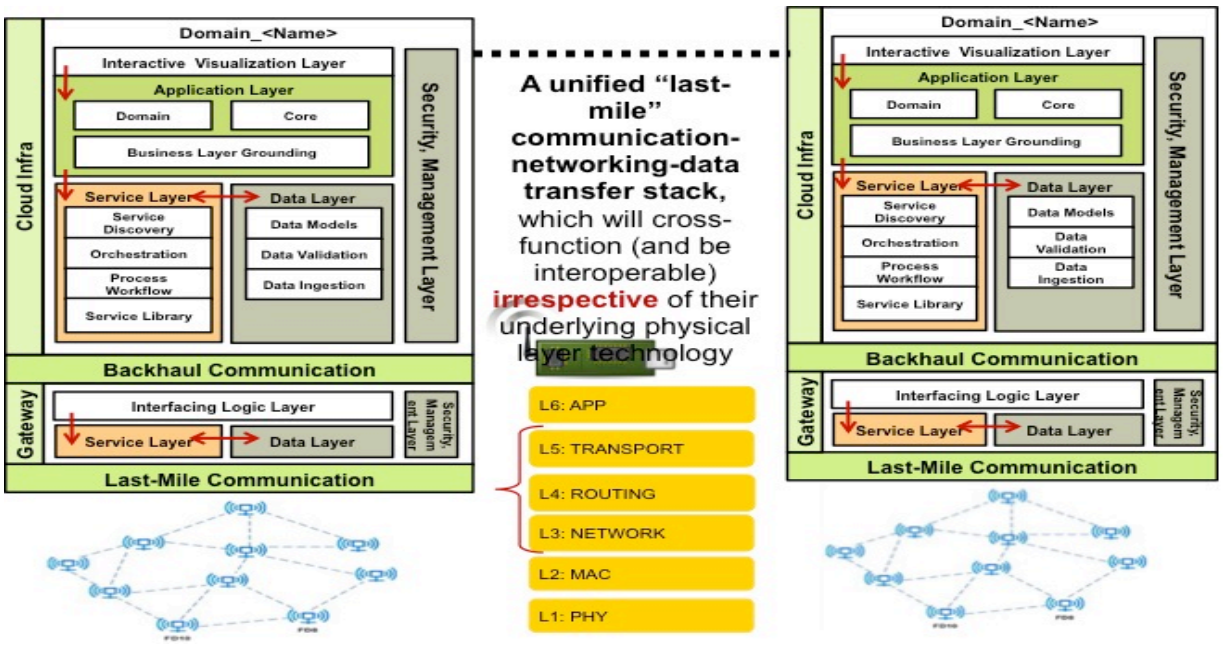
This approach of unifying the Layer 3 to Layer 7 shall bring Interoperability to the Last mile, by implementing the unified stack in all the communication modules in the Smart Infrastructure Domain, irrespective of the communication Technology used in different deployment scenarios.



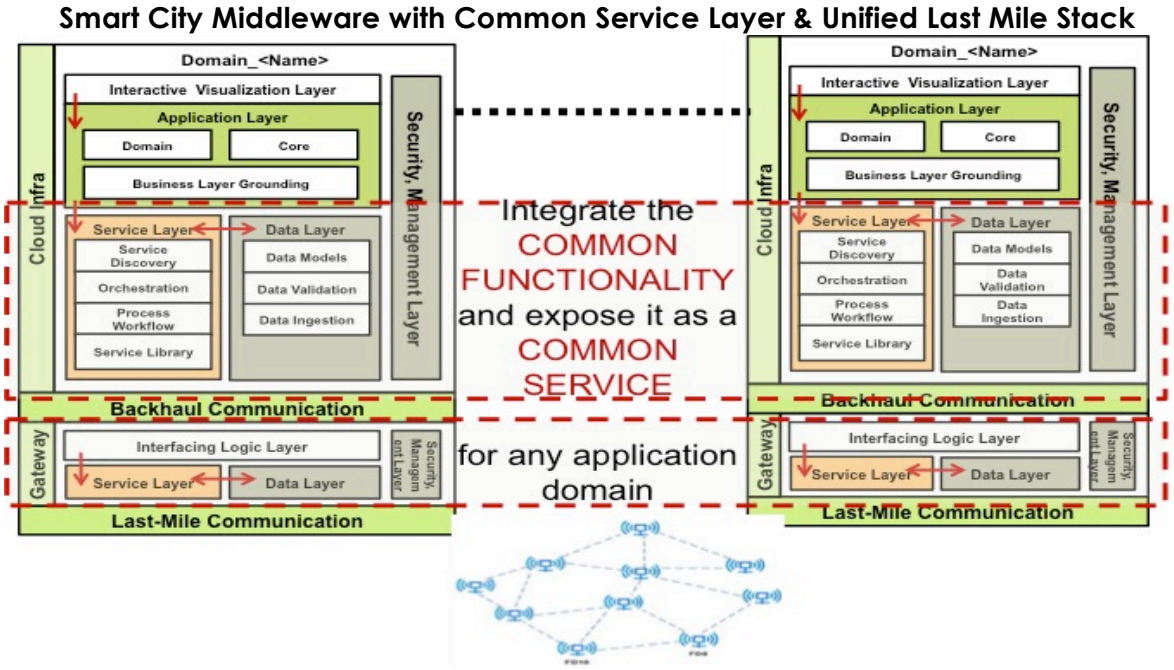
Current Bouquet of Communication Technologies, Protocols & Standards

Hence, such Unified Stack along with Common Service Layer in the Gateways and the Cloud, backed by a common Cloud based IT Framework and unified Data Repository shall bring a comprehensive optimization in the ICT Infrastructure in any given Geographical territory, be it a Smart City, a Smart District, a State or even a Smart Nation.

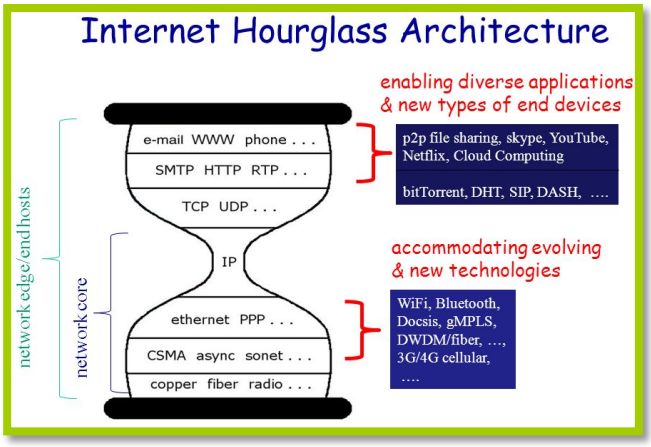
Functional Architecture: Unifying & Harmonizing the "Last-mile" Madness

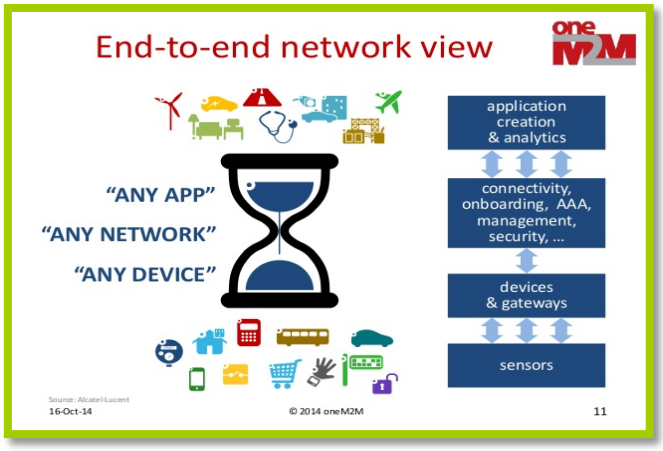


Functional Architecture:



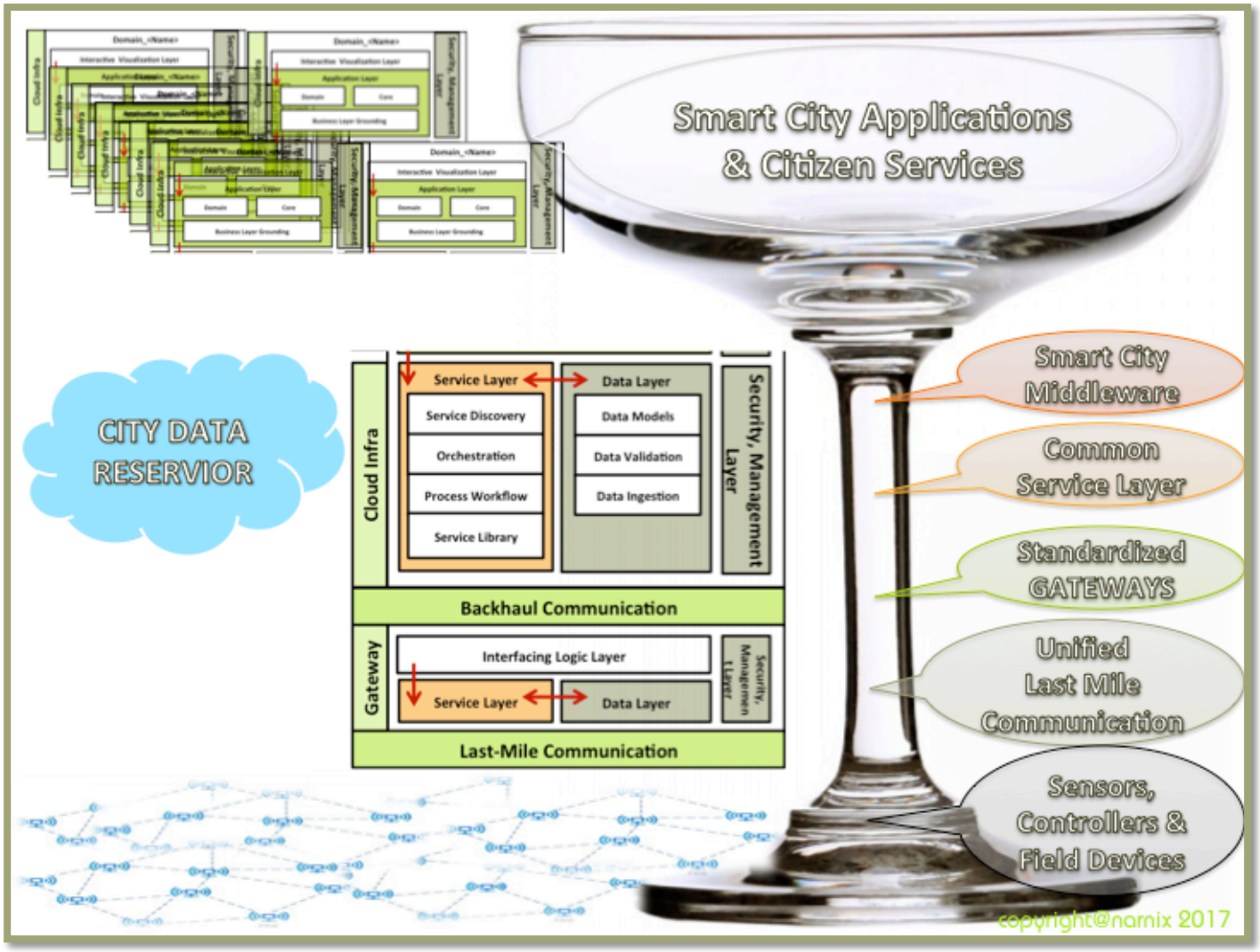
Unified ICT Architecture Abstraction:





Moving from Hour Glass Architecture to…

…Classic Saucer Champagne Glass Architecture:



Classic Saucer Champagne Glass Model

The evolved Comprehensively Unified ICT Architecture can be modelled as a **"Classic Saucer Champagne Glass"** with a wide Flat Bottom Base depicting the multitude of Field Devices & sensors etc. The Saucer Shaped Bowl on the Top depicting being filled with an ever-increasing spectrum of City Applications and Citizens' Services. The **Long Stem** depicts all the **Common Layers** viz.: the Unified Last Mile Communication, Common Standardized Gateways (application or Vertical Agnostic), Common Service layer representing the Common Service Functions in the **Gateways**, as well as, in the **Cloud**… and the Smart City Middleware & City Data Reservoir in the Cloud.

It is the "Long Stem" of the "Champagne Glass Model" instead of the Short & Narrow Neck in the "Hourglass Model" that brings the comprehensive harmonization, standardization & interoperability in the Architecture leading to optimization in operational efficiency & Life Cycle Cost of the ICT Infrastructure in any Smart City.

Conclusion:

Smart projects are often connected to other aspects of infrastructure, and should be thought of as large systems of systems, the success of which relies on the optimization of all the sub-systems that support it. Some of the earliest deployments of smart infrastructure have proven to be not so smart. Most deployments have failed to identify dependencies or interactions with adjacent systems, impacting overall performance and restricting functionality.

The convergence of multiple networks and technologies, particularly in new and emerging markets involving large-scale infrastructures require a top-down approach to standardization, starting at System Architecture rather than at product level.

The systems level approach recommended above in design and standardization is likely to not only enable newer and better services, but also allow far greater synergies and cost-effective deployments, reducing the lifecycle (total) cost of ownership of any Infrastructure, be it the grid, a home, a building or even a city, with attendant environmental benefits, including carbon reductions and building system resilience.

An integrated approach to Smart Infrastructure assets can help define and strengthen the System standards throughout the technical community to ensure that highly complex market sectors can be properly supported for the increasing conformity, harmonization and convergence of both Information Technologies (IT) and Operational Technologies (OT) systems.

There is a need to focus on the creation of a secure, standardized and open infrastructure model for the delivery of services. The concept combines standards-based, end-to-end software with a converged smart infrastructure gateway/DCU design to establish a common, open framework for secured service delivery and management.

"A 'box' (or service gateway) built on such a platform can consolidate boxes from utilities and/or multiple service providers into a single, unified BOX that can support multiple service providers and utilities. In wake of the proliferation of 'IoT', a new paradigm of "Fog Computing", beyond the "Cloud Computing" is evolving rapidly. In this paradigm where the storage and intelligence moves from the "cloud" to the "edge" the standardization, harmonization and the interoperability take a pivotal role for operational efficiency of the "Smart Infrastructure".

This approach, if adopted to define the framework and architecture for Smart Infrastructure, shall lead to tremendous savings and optimisation of CAPEX & OPEX of the "Smart, Sustainable & Secure Cities", as well as lead to drastic reduction in the 'Carbon Footprint' of the ICT Infrastructure in any earmarked geographical territory.

The major focus of the exercise was to develop the framework for such a unified, harmonized and yet standards based Comprehensive ICT Infrastructure, including:

- ⇨ *The "end to end last mile communication protocol" defining explicitly and comprehensively layer by layer, frame by frame with complete interoperability at the network, semantic or at syntactic level.*
- ⇨ *The Common Service Layer Framework for Diverse applications and use cases with standardized common service functions.*
- ⇨ *The Unified IT Architecture based on Enterprise Architecture enabled by Service*

Oriented Architecture Methodology with Unified Data Reservoir/Repository for structured, as well as, unstructured data in the city.

It is hoped that if a Reference Solutions based on such an approach could be developed, it could be used as a Road Test for the standards in the field of Unified Information & Communication Architecture for 'Smart City' and 'Smart Infrastructure'.

This Reference Framework shall help define n create **sharable** common elements that shall be interoperable across verticals & hence reduce the Infrastructures' CAPAX & OPEX.

NEXT STEPS:

- ⇨ Develop Comprehensively Granular Reference Architecture for Unified Secure & Resilient ICT Backbone…
- ⇨ Map relevant Standards to the different blocks & Layers of the Reference Architecture & identify Gaps.
- ⇨ Develop New Standards to fill the Gaps.

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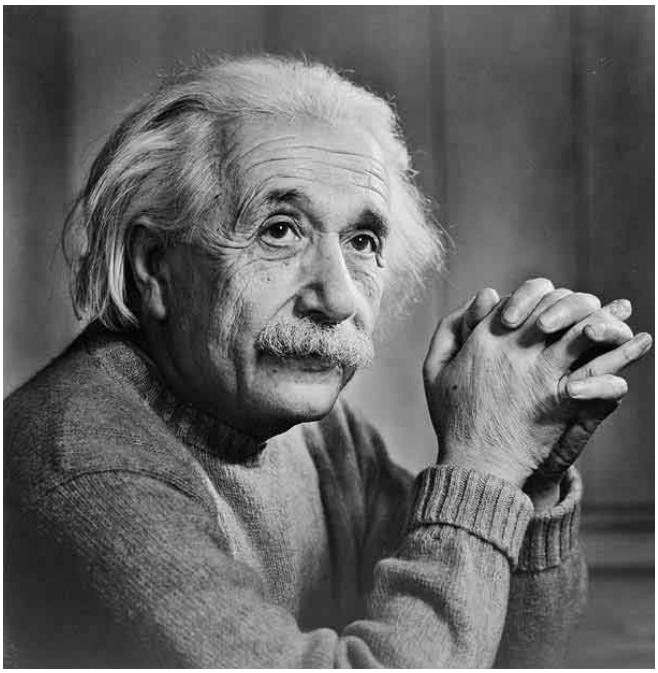
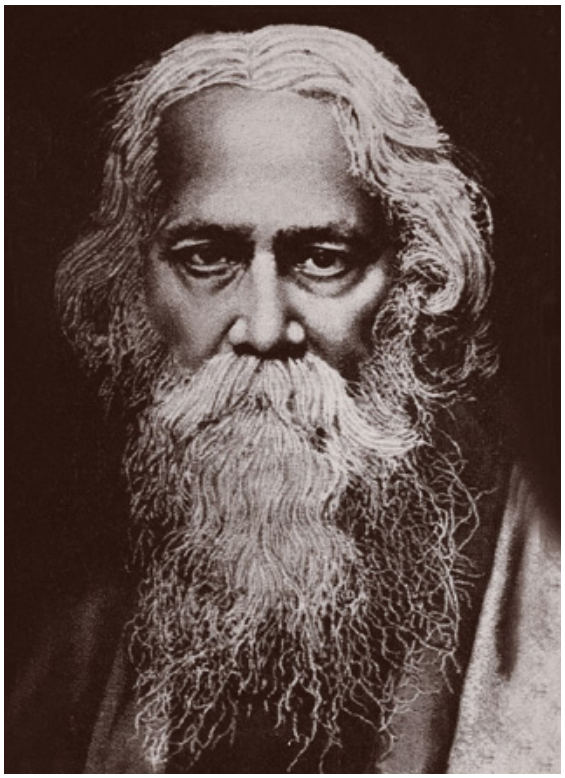
Building
a smart, sustainable, secure n resilient city
is a big challenge



"The same way of thinking that got you into trouble won't get you out of it."



"Let us not pray to be sheltered from dangers but to be fearless when facing them

Standards are the chromosomes of Smart Infrastructure

Standards make Cities Smarter